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FINAL REPORT An Assessment of Sea Scallop Abundance and Distribution in Selected Closed Areas: Georges Bank Area I and II, Nantucket Lightship and Elephant Trunk

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Project Summary

As the spatial and temporal dynamics of marine ecosystems have recently become better understood, the concept of entirely closing or limiting activities in certain areas has gained support as a method to conserve and enhance marine resources. In the last decade, the sea scallop resource has benefited from measures that have closed specific areas to fishing effort. As a result of closures on both Georges Bank and in the mid-Atlantic region, biomass of scallops in those areas has expanded. As the time approaches for the fishery to harvest scallops from the closed areas, quality, timely and detailed stock assessment information is required for managers to make informed decisions about the re-opening.

During May through October of 2007, three experimental cruises were conducted aboard commercial sea scallop vessels. At pre-determined sampling stations within the exemption areas of Georges Bank Closed Area I (CAI) Georges Bank Closed Area II (CAII), the Nantucket Lightship Closed Area (NLCA) and the entire Elephant Trunk Closed Area (ETCA) both a NMFS survey dredge and a standard commercial dredge were simultaneously towed. From these cruises, fine scale survey data was used to assess scallop abundance and distribution in the closed areas. This data will also provide a comparison of the utility of using two different gears as survey tools in the context of industry based surveys. The results of this study will provide additional information in support of upcoming openings of closed areas within the context of rotational area management.

Project Background

The sea scallop, *Placopecten magellanicus,* supports a fishery that in 2006 landed 59 million pounds of meats with an ex-vessel value of US $386 million. These landings resulted in the sea scallop fishery being the second most lucrative fishery along the East Coast of the United States (Van Voorhees, 2007). While historically subject to extreme cycles of productivity, the fishery has benefited from recent management measures intended to bring stability and sustainability. These measures included: limiting the number of participants, total effort (days-at-sea), gear and crew restrictions and most recently, a strategy to improve yield by protecting scallops through rotational area closures.

Amendment #10 to the Sea Scallop Fishery Management Plan officially introduced the concept of area rotation to the fishery. This strategy seeks to increase the yield and reproductive potential of the sea scallop resource by identifying and protecting discrete areas of high densities of juvenile scallops from fishing mortality. By delaying capture, the rapid growth rate of scallops is exploited to realize substantial gains in yield over short time periods. In addition to the formal attempts found in Amendment #10 to manage discrete areas of scallops for improved yield, specific areas on Georges Bank are also subject to area closures. In 1994, 17,000 km^2 of bottom were closed to any fishing gears capable of capturing groundfish. This closure was an attempt to aid in the rebuilding of severely depleted species in the groundfish complex. Since scallop dredges are capable of capturing groundfish, scallopers were also excluded from these areas. Since 1999, however, limited access to the three closed areas on Georges Bank has been allowed to harvest the dense beds of scallops that have accumulated in the absence of fishing pressure.

In order to effectively regulate the fishery and carry out a robust rotational area management strategy, current and detailed information regarding the abundance and distribution of sea scallops is essential. Currently, abundance and distribution information gathered by surveys comes from a variety of sources. The annual NMFS sea scallop survey provides a comprehensive and synoptic view of the resource from Georges Bank to Virginia. In contrast to the NMFS survey that utilizes a dredge as the sampling gear, the resource is also surveyed photographically. Researchers from the School for Marine Science and Technology (SMAST) are able to enumerate sea scallop abundance and distribution from images taken by a camera system mounted on a tripod lowered to the substrate (Stokesbury, 2002). Prior to the utilization of the camera survey and in addition to the annual information supplied by the NMFS annual survey, commercial vessels were contracted to perform surveys. Dredge surveys of the following closed areas have been successfully completed by the cooperative involvement of industry, academic and governmental partners: CAII was surveyed in 1998, CAI, NLCA, Hudson Canyon Closed Area (HCCA) and Virginia Beach Closed Area (VBCA) in 1999, HCCA and VBCA in 2000, NLCA, CAII and the ETCA in 2005 and CAI, NLCA and ETCA in 2006. The additional information provided by these surveys was vital in the determination of appropriate Total Allowable Catches (TAC) in the subsequent re-openings of the closed areas. This type of survey, using commercial

fishing vessels, provides an excellent opportunity to gather required information and also involve stakeholders in the management of the resource.

The recent passing of Amendment #10 has set into motion changes to the sea scallop fishery that are designed to ultimately improve yield and create stability. This stability is an expected result of a spatially explicit rotational area management strategy where areas of juvenile scallops are identified and protected from harvest until they reach an optimum size. Implicit to the institution of the new strategy, is the highlighted need for further information to both assess the efficacy of an area management strategy and provide that management program with current and comprehensive information. In addition to rotational management areas, access to the scallop biomass encompassed by the Georges Bank Closed Areas is vital to the continued prosperity of the fishery.

The survey cruises conducted during the spring/summer of 2007 supported effective area management by providing a timely and detailed assessment of the abundance and distribution of sea scallops in the access areas of CAI, CAII, NLCA and the entire ETCA. The information gathered on these survey cruises will augment information gathered by the annual NMFS sea scallop survey which provides a comprehensive and synoptic view of the resource from Georges Bank to Virginia. The breadth of this sampling, however, may preclude the collection of fine scale information. Due to the patchy nature of scallop aggregations, inference regarding smaller resource subunits may be uncertain. Therefore, fine scale information from this survey will be used to assess the distribution and biomass of exploitable size scallops in the CAI Access Area, CAII Access Area, NLSA Access Area and the ETCA.

Methods

Survey Areas and Experimental Design

Four closed areas were surveyed during the course of this project: three areas on Georges Bank and one area in the Mid-Atlantic. The exemption areas of CAI, CAII and NLSA and the entire ETCA were sampled. The coordinates of the surveyed areas can be found in Table 1.

The sampling stations for this study were selected within the context of a systematic random grid. With the patchy distribution of sea scallops determined by

some unknown combination of environmental gradients (i.e. latitude, depth, hydrographic features, etc.), a systematic selection of survey stations results in an even dispersion of samples across the entire sampling domain. The systematic grid design was successfully implemented during industry-based surveys since 1998. This design has also been utilized for the execution of a trawl survey in the Bering Sea (Gunderson, 1993).

The methodology to generate the systematic random grid entailed the decomposition of the domain (in this case a closed area) into smaller sampling cells. The dimensions of the sampling cells were primarily determined by a sample size analysis conducted using the catch data from survey trips conducted in the same areas during the prior year. Since the four closed areas were of different dimensions and the total number of stations sampled per survey varied, the distance between the stations was not constant. Once the cell dimensions were set, a point within the most northwestern cell was randomly selected. This point served as the starting point and all of the other stations in the grid were based on its coordinates. The station locations for the four closed areas surveyed are shown in Figures 1-3.

Sampling Gear

While at sea, the vessels simultaneously towed two dredges. A NMFS standard survey dredge, 8 feet in width equipped with 2-inch rings, 4-inch diamond twine top and a 1.5 inch diamond mesh liner was towed on one side of the vessel. On the other side of the vessel, a 15 or 14 foot commercial scallop dredge equipped with 4-inch rings, a 10-inch diamond mesh twine top and no liner was utilized. Position of twine top within the dredge bag was standardized throughout the study and rock chains were used in configurations as dictated by the area surveyed and current regulations. In this paired design, it is assumed that the dredges cover a similar area of substrate and sample from the same population of scallops. The dredges were switched to opposite sides of the vessel mid-way throughout the trip to help minimize any bias.

For each survey tow, the dredges were fished for 15 minutes with a towing speed of approximately 3.8-4.0 kts. High-resolution navigational logging equipment was used to accurately determine vessel position. Time stamps recorded on the navigational log were used in conjunction with tow start/stop times recorded on the bridge log to estimate area swept by the gear.

Sampling of the catch was performed using the protocols established by DuPaul and Kirkley, 1995 and DuPaul *et. al.* 1989. For each survey tow, the entire scallop catch was placed in baskets. Depending on the total volume of the catch, a fraction of these baskets were measured for sea scallop length frequency. The shell height of each scallop in the sampled fraction was measured on NMFS sea scallop measuring boards in 5 mm intervals. This protocol allows for the estimation of the size frequency for the entire catch by expanding the catch at each shell height by the fraction of total number of baskets sampled. Finfish and invertebrate bycatch were quantified, with finfish being sorted by species and measured to the nearest 1 cm.

Samples were taken to determine area specific shell height-meat weight relationships. At roughly 20 randomly selected stations the shell height of a sample of 10 scallops was measured to the nearest 0.1 mm. These scallops were then carefully shucked and the adductor muscle individually packaged and frozen at sea. Upon return, the adductor muscle was weighed to the nearest 0.1 gram. The relationship between shell height and meat weight was estimated in log-log space using linear regression procedures in SAS v. 9.0. with the model:

$$\ln MW = \ln a + b * \ln SH$$

where MW=meat weight (grams), SH=shell height (millimeters), a=intercept and b=slope.

The standard data sheets used since the 1998 Georges Bank survey were used. The bridge log maintained by the captain/mate recorded location, time, tow-time (break-set/haul-back), tow speed, water depth, catch, bearing, weather and comments relative to the quality of the tow. The deck log maintained by the scientific personnel recorded detailed catch information on scallops, finfish, invertebrates and trash.

Data Analysis

The catch, and navigation data were used to estimate swept area biomass within the areas surveyed. The methodology to estimate biomass is similar to that used in analyzing the data from the 1998 survey of CAII and the 1999-2000 survey of the Mid-Atlantic closed areas. It is calculated by the following:

$$TotalBiomass = \sum_{j} \left(\frac{\left(\frac{CatchWtperTowinSubarea_j}{AreaSweptperTow} \right)}{Efficiency} \right) SubArea_j$$

Catch weight per tow

Catch weight per tow of exploitable scallops was calculated from the raw catch data as an expanded size frequency distribution with an area and depth appropriate shell height-meat weight relationship applied (length-weight relationships were obtained from SARC 45 document, and actual relationships taken during the cruise) (NEFSC, 2007). Exploitable biomass, defined as that fraction of the population vulnerable to capture by the currently regulated commercial gear, was calculated differently for the two survey gear configurations used. The observed catch at length data from the NMFS survey dredge (assumed to be non size selective) was adjusted based upon the size selectivity characteristics of the commercial gear (Yochum and DuPaul, 2008). The observed catch at length data from the commercial dredge was not adjusted due to the fact that these data already represent that fraction of the population that is subject to exploitation by the currently regulated commercial gear.

Area Swept per tow

Utilizing the information obtained from the high resolution GPS, an estimate of area swept per tow was calculated. Throughout the cruises the location of the ship was logged every three seconds. By determining the start and end of each tow based on the recorded times of brake set/haul back initiation, a survey tow can be represented by a series of consecutive coordinates (latitude, longitude). The linear distance of the tow is calculated by:

$$TowDist = \sum_{i=1}^{n} \sqrt{\left(long_2 - long_1\right)^2 + \left(lat_2 - lat_1\right)^2}$$

The linear distance of the tow is multiplied by the width of the gear to result in an estimate of the area swept by the gear during a given survey tow.

Efficiency and Domain

The final two components of the estimation of biomass are constants and not determined from experimental data obtained on these cruises. Estimates of gear efficiency have been calculated from prior experiments using a variety of approaches (Gedamke *et. al.,* 2005, Gedamke *et. al.,* 2004, D. Hart, pers. comm.). Based on those experiments and consultations with NEFSC, a efficiency value of 32% was used for the trips on Georges Bank (CAI, CA II and NLCA) and 40% was used in the mid-Atlantic (ETCA) for the NMFS survey dredge (D. Hart, pers. comm.). The efficiency estimates for the commercial dredge were higher in both areas. For the Georges closed areas, a value of 40% was used and a value of 60% was used in the mid-Atlantic region. The total area each closed area sampled was calculated in ArcView v. 3.3. This area was applied to scale the mean catch per survey tow to the appropriate area of interest.

Results

Three survey cruises were completed between May and October of 2007. Summary statistics for each cruise are shown in Table 2. Catch information is shown in Table 3 and length frequency distributions for each trip are shown in Figures 4-7. Maps depicting the spatial distribution of the catches of pre-recruit (<90 mm shell height), and fully recruited (≥90mm shell height) scallops from both the commercial and survey dredges are shown in Figures 8-19. Based on the catch data, estimates of scallop density for each area is shown in Table 4 and estimated exploitable biomass using two different sets of shell height meat weight parameters are shown in Table 5. Shell height meat weight relationships were generated for all areas. The resulting parameters as well as the parameters from SARC 45 are shown in Table 6. Catch per unit effort of finfish and invertebrate bycatch for the three cruises is shown in Tables 7-10.

Discussion

Fine scale surveys of closed areas area an important endeavor. These surveys provide information about subsets of the resource that may not have been subject to intensive sampling by other efforts. Additionally, the timing of industry-based surveys can be tailored to give managers current information to guide important management

decisions. This information can help time access to closed areas and help set Total Allowable Catches (TAC) for the re-opening. Finally, this type of survey is important in that it involves the stakeholders of the fishery in the management of the resource.

The use of commercial scallop vessels in a project of this magnitude presents some interesting challenges. One such challenge is the use of the commercial gear. This gear is not designed to be a survey gear; it is designed to be efficient in a commercial setting. The design of this current experiment however provides insight into the utility of using a commercial gear as a survey tool. The concurrent use of two different dredge configurations provides an excellent test for agreement of results. With a paired design, it is assumed that the two gears cover the same bottom and sample from the same population of scallops. The expectation that after applying the appropriate adjustment factors to compensate for gear performance issues the estimates of biomass for the two gears will be comparable. Based on the biomass estimates for the four areas, there is a clear trend that indicates biomass values from the commercial gear are higher relative to those from the NMFS survey gear. The possibility exists that there is a differential efficiency between the two gears greater than what was indicated in the literature (NEFSC 2007, Gedamke *et. al.,* 2005, Gedamke *et. al.,* 2004, D. Hart, pers. comm.) Information from the selectivity analysis conducted by Yochum and DuPaul, (2008) indicate that, at least on a relative basis (based on the estimates of the split parameter, p) the commercial gear is more efficient. While much work has been done to estimate the efficiency of the commercial dredge, there has been little effort devoted to examining the overall efficiency of the NMFS survey dredge (Gedamke *et. al.,* 2005, Gedamke *et. al.,* 2004, D. Hart, pers. comm.). To increase the utility of the NMFS survey dredge from a tool that produces a relative index to one that is fine-tuned to produce absolute biomass estimates, the efficiency question should be viewed as a high priority.

Based on the results of this study, the commercial gear has the potential to be an effective sampling gear under some circumstances. Due to the selective properties of a dredge equipped with 4.0 inch rings, it will never be an effective tool for sampling small scallops. Its strength lies in sampling exploitable size scallops (> 80 mm shell height). Although the selectivity work by Yochum and DuPaul (2008) provide an experimental basis to calculate the length based retention probabilities for the commercial gear, detection of recruitment events in their early stages will never be an attribute of the commercial gear.

Biomass estimates are sensitive to other assumptions made about the biological characteristics of the resource; specifically, the use of appropriate shell height meat weight parameters. Parameters generated from data collected during the course of the study were appropriate for the area and time sampled. There is however, a large variation in this relationship as a result of many factors. Seasonal variation can result in some of the largest differences in shell height meat weight values. Traditionally, when the sea scallop undergoes its annual spawning cycle the somatic tissue of the scallop is still recovering and is at some of their lowest levels relative to shell size (Serchuk and Smolowitz, 1989). While accurately representative for the month of the survey, biomass has the potential to be different relative during other times of the year. For comparative purposes, our results were also shown using the parameters from SARC 45 (NEFSC, 2007). These parameters reflect larger geographic regions (mid-Atlantic & Georges Bank) and are collected during the summer months. This allowed a comparison of results that may be reflective of some of the variations in biomass due to the fluctuations in the relationship between shell height and adductor muscle weight. Area and time specific shell height: meat weight parameters are another topic that merits consideration.

The survey of the three closed areas during the spring/summer of 2006 provided a high-resolution view of the resource in those discrete areas. These closed areas are unique in that they play varied roles in the spatial management of the sea scallop resource. While the data and subsequent analyses provide an additional source of information on which to base management decisions, it also highlights the need for further refinement of some of the components of industry based surveys. The use of industry based cooperative surveys provides an excellent mechanism to obtain the vital information to effectively regulate the sea scallop fishery in the context of an area management strategy.

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Table 1 Boundary coordinates of sea scallop closed areas sampled during 2007.

Area Surveyed	Latitude	Longitude
Georges Bank CAII (exemption area)		
GBCAII -1	41° 00’ N	67° 20’ W
GBCAII -2	41° 00’ N	66° 35.8’ W
GBCAII -3	41° 18.6’ N	66° 24.8’ W
GBCAII -4	41° 30’ N	66° 34.8’ W
GBCAII -5	41° 30’ N	67° 20’ W
Nantucket Lightship (exemption area)		
NLSA-1	40° 50’ N	69° 00’ W
NLSA-2	40° 30’ N	69° 00’ W
NLSA-3	40° 30’ N	69° 4.5’ W
NLSA-4	40° 50’ N	69° 29.5’ W
Closed Area I Access Area (current)		
CAI-1	41° 26’ N	68° 30’ W
CAI-2	41° 09’ N	68° 30’ W
CAI-3	41° 4.54’ N	69° 0.9’ W
Elephant Trunk		
ET-1	38° 50’ N	74° 20’ W
ET-2	38° 10’ N	74° 20’ W
ET-3	38° 10’ N	73° 30’ W
ET-4	38° 50’ N	73° 30’ W

Table 2 Summary statistics for the survey cruises.

Area	Cruise dates	Number of stations included in biomass estimate (survey dredge)	Number of stations included in biomass estimate (comm. dredge)
Exemption Area-Georges Bank Closed Area II	May 24-31,2007	94	93
Exemption Area-Nantucket Lightship Close Area	September 16-18, 2007	48	48
Exemption Area-Georges Bank Closed Area I	September 18-20, 2007	29	29
Elephant Trunk Closed Area	October 20-26, 2007	98	97

Table 3 Mean catch of sea scallops observed during the 2007 VIMS-Industry cooperative closed area surveys. Mean catch is depicted as a function of two different shell height meat weight relationships, either an area specific relationship derived from samples taken during the survey or a regional relationship from SARC 45.

Gear	Samples	SH:MW	Efficiency	Mean (grams/tow)	Standard Error
GBCAII					
Commercial	93	May, 2007	45%	11,015.3	1,431.5
Survey	94	May, 2007	32%	3,301.3	326.2
Commercial	93	SARC 45	45%	8,631.9	1,079.1
Survey	94	SARC 45	32%	2,617.2	248.5
NLCA					
Commercial	48	September, 2007	45%	49,114.6	9,425.6
Survey	48	September, 2007	32%	13,351.2	3,202.5
Commercial	48	SARC 45	45%	41,744.3	7,924.4
Survey	48	SARC 45	32%	11,200.2	2,649.2
GBCAI					
Commercial	29	September, 2007	45%	18,616.9	3.626.6
Survey	29	September, 2007	32%	7,549.1	2,158.1
Commercial	29	SARC 45	45%	18,754.8	3,356.8
Survey	29	SARC 45	32%	7,489.5	2,007.0
ETCA					
Commercial	97	October, 2007	60%	52,699.8	6,333.0
Survey	98	October, 2007	40%	15,764.9	1,750.7
Commercial	97	SARC 45	60%	59,129.7	6,919.1
Survey	98	SARC 45	40%	17,755.2	1,938.2

Table 4 Mean total and mean exploitable scallop densities observed during the 2007 cooperative sea scallop surveys.

Gear	Efficiency	Average Total Density (scallops/m^2)	SE	Average Density of Exploitable Scallops (scallops/m^2)	SE
GBCAII					
Commercial	45%			0.070	0.010
Survey	32%	0.118	0.018	0.050	0.005
NLCA					
Commercial	45%			0.255	0.048
Survey	32%	0.268	0.053	0.175	0.039
GBCAI					
Commercial	45%			0.117	0.021
Survey	32%	0.168	0.042	0.123	0.036
ETCA					
Commercial	60%			0.474	0.071
Survey	40%	0.544	0.078	0.339	0.044

Table 5 Estimated exploitable biomass of sea scallops observed during the 2007 VIMS-Industry cooperative closed area surveys. Biomass is depicted as a function of two different shell height meat weight relationships, either an area specific relationship derived from samples taken during the survey or a regional relationship from SARC 45.

Gear	SH:MW	Efficiency	Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
GBCAII						
Commercial	May 2007	45%	11,147.7	1,904.8	9,242.9	13,052.6
Survey	May 2007	32%	8,808.5	965.1	7,843.4	9,773.6
Commercial	SARC 45	45%	8,735.7	1,435.9	7,299.7	10,171.7
Survey	SARC 45	32%	6,983.2	735.1	6,248.0	7,718.4
NLCA						
Commercial	September, 2007	45%	15,017.6	3,789.3	11,228.3	18,807.0
Survey	September, 2007	32%	10,764.0	2,862.7	7,901.1	13,626.8
Commercial	SARC 45	45%	12,764.0	3,185.8	9,578.2	15,949.8
Survey	SARC 45	32%	9,029.8	2,368.1	6,661.7	11,397.9
GBCAI						
Commercial	September, 2007	45%	3,304.1	846.2	2,457.8	4,150.4
Survey	September, 2007	32%	3,527.5	1,118.1	2,409.4	4,609.4
Commercial	SARC 45	45%	3,328.6	783.3	2,545.3	4,112.0
Survey	SARC 45	32%	3,499.7	1,039.8	2,459.8	4,539.5
ETCA						
Commercial	October, 2007	60%	50,768.4	9,262.5	41,505.9	60,030.9
Survey	October, 2007	40%	39,875.3	5,489.3	34,385.9	45,364.7
Commercial	SARC 45	60%	56,962.6	10,119.7	46,842.9	67,082.3
Survey	SARC 45	40%	44,909.5	6,067.8	38,841.6	50,977.4

Table 6 Summary of area specific shell height-meat weight parameters as generated by samples collected during the course of the surveys (May, September and October of 2007) and the parameters from SARC 45 (NEFSC, 2007)*.

Area surveyed	Date	α	β	γ
Survey data				
GBCAII	May, 2007	-10.981	3.030	-
NLCA	September, 2007	-11.06	3.0061	-
GBCAI	September, 2007	-10.981	3.03	-
ETCA	October, 2007	-13.132	3.444	-
SARC 45				
Georges Bank	-	-8.62	2.95	-0.51
Mid-Atlantic	-	-9.18	3.18	-0.65

*For data collected aboard the survey cruises, the length-weight relationship was modeled as:

$$W=\exp(\alpha+\beta\ln(L))$$

The length weight relationship for sea scallops from SARC 45 is modeled as:

$$W=\exp(\alpha+\beta\ln(L)+\gamma\ln(D))$$

Where W is meat weight in grams, L is scallop shell height in millimeters (measured from the umbo to the ventral margin) and D is depth in meters.

Table 7 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish and invertebrate bycatch encountered during the survey of the exemption area in the Georges Bank Closed Area II during May 2007. In total, finfish and invertebrate bycatch was measured and recorded for 94 survey tows.

Common Name	Scientific Name	Commercial Dredge	Survey Dredge
Unclassified Skates	*Raja spp.*	7.915	7.691
Barndoor Skate	*Raja laevis*	0.872	0.191
Silver Hake	*Merluccius bilinearis*	0.000	0.053
Haddock	*Melanogrammus aeglefinus*	0.011	0.266
Red Hake	*Urophycis shuss*	0.117	3.734
American Plaice	*Hippoglossoides platessoides*	0.074	0.457
Summer Flounder	*Paralichtys dentatus*	0.021	0.032
Fourspot Flounder	*Paralichtys oblongotus*	0.309	0.883
Yellowtail Flounder	*Limanda ferruginea*	2.872	7.191
Blackback Flounder	*Psuedopleuronectes americana*	0.032	0.053
Witch Flounder	*Glyptocephalus cynoglossus*	0.309	0.287
Windowpane Flounder	*Scophthalmus aquasus*	1.511	1.319
Gulfstream Flounder	*Citharichthys arctifrons*	0.000	0.670
Sculpin uncl.	*Cottidae*	0.043	0.638
Sea Raven	*Hemitripterus americanus*	0.085	0.106
Fawn Cusk Eel	*Lepophidium profundorum*	0.000	0.170
Monkfish	*Lophius americanus*	1.500	0.862
Eelpout Uncl.	*Zoarcidae*	0.032	0.638
American lobster	*Homarus americanus*	0.021	0.000
Squid Uncl.	*Cephalopoda*	0.000	0.043

Table 8 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish and invertebrate bycatch encountered during the survey of the exemption area in the Nantucket Lightship Closed Area during September 2007. In total, finfish and invertebrate bycatch was measured and recorded for 48 survey tows.

Common Name	Scientific Name	Commercial Dredge	Survey Dredge
Unclassified Skates	*Raja spp.*	29.625	17.224
Barndoor Skate	*Raja laevis*	0.729	0.125
Silver Hake	*Merluccius bilinearis*	0.333	2.063
Red Hake	*Urophycis shuss*	1.146	7.958
Summer Flounder	*Paralichtys dentatus*	0.146	0.146
Fourspot Flounder	*Paralichtys oblongotus*	0.396	5.000
Yellowtail Flounder	*Limanda ferruginea*	2.292	5.708
Blackback Flounder	*Psuedopleuronectes americana*	0.188	0.938
Witch Flounder	*Glyptocephalus cynoglossus*	0.021	0.646
Windowpane Flounder	*Scophthalmus aquasus*	1.563	3.708
Gulfstream Flounder	*Citharichthys arctifrons*	0.000	2.500
Sea Raven	*Hemitripterus americanus*	0.292	4.854
Armored Searobin	*Peristedion miniatum*	0.333	0.396
Fawn Cusk Eel	*Lepophidium profundorum*	0.125	3.458
Monkfish	*Lophius americanus*	1.271	0.750
American lobster	*Homarus americanus*	0.000	0.021

Table 9 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish and invertebrate bycatch encountered during the survey of the exemption area in Georges Bank Closed Area I during September 2007. In total, finfish and invertebrate bycatch was measured and recorded for 29 survey tows.

Common Name	Scientific Name	Commercial Dredge	Survey Dredge
Spiny dogfish	*Squalus acanthias*	0.000	0.069
Unclassified Skates	*Raja spp.*	26.103	10.414
Barndoor Skate	*Raja laevis*	2.793	0.586
Silver Hake	*Merluccius bilinearis*	0.000	0.069
Haddock	*Melanogrammus aeglefinus*	0.034	0.000
Red Hake	*Urophycis shuss*	0.448	21.931
American Plaice	*Hippoglossoides platessoides*	0.034	0.000
Summer Flounder	*Paralichtys dentatus*	0.414	0.345
Fourspot Flounder	*Paralichtys oblongotus*	0.517	1.241
Yellowtail Flounder	*Limanda ferruginea*	1.069	1.621
Blackback Flounder	*Psuedopleuronectes americana*	1.207	1.069
Witch Flounder	*Glyptocephalus cynoglossus*	0.103	0.069
Windowpane Flounder	*Scophthalmus aquasus*	0.379	0.069
Gulfstream Flounder	*Citharichthys arctifrons*	0.000	0.069
Sculpin uncl.	*Cottidae*	0.310	0.655
Sea Raven	*Hemitripterus americanus*	0.138	1.000
Armored Searobin	*Peristedion miniatum*	0.069	0.034
Fawn Cusk Eel	*Lepophidium profundorum*	0.000	2.000
Monkfish	*Lophius americanus*	3.897	2.690

Table 10 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish and invertebrate bycatch encountered during the survey of the Elephant Trunk Closed Area during October 2007. In total, finfish and invertebrate bycatch was measured and recorded for 97 and 98 survey tows for the commercial and NMFS survey dredge, respectively.

Common Name	Scientific Name	Commercial Dredge	Survey Dredge
Spiny dogfish	*Squalus acanthias*	0.000	0.010
Unclassified Skates	*Raja spp.*	17.546	10.694
Silver Hake	*Merluccius bilinearis*	0.010	0.337
Red Hake	*Urophycis shuss*	0.052	0.449
Summer Flounder	*Paralichtys dentatus*	0.021	0.020
Fourspot Flounder	*Paralichtys oblongotus*	0.649	3.551
Windowpane Flounder	*Scophthalmus aquasus*	0.175	0.153
Gulfstream Flounder	*Citharichthys arctifrons*	0.021	2.510
Butterfish	*Peprilus triacanthus*	0.000	0.020
Armored Searobin	*Peristedion miniatum*	0.113	0.082
Fawn Cusk Eel	*Lepophidium profundorum*	0.000	0.020
Monkfish	*Lophius americanus*	1.278	0.806
Eelpout Uncl.	*Zoarcidae*	0.000	0.041
American lobster	*Homarus americanus*	0.000	0.010
Squid Uncl.	*Cephalopoda*	0.186	1.102

Figure 1 Locations of sampling stations in the exemption area of Georges Bank Closed Area II survey by the F/V *Celtic* during the cruise conducted during May 2007.

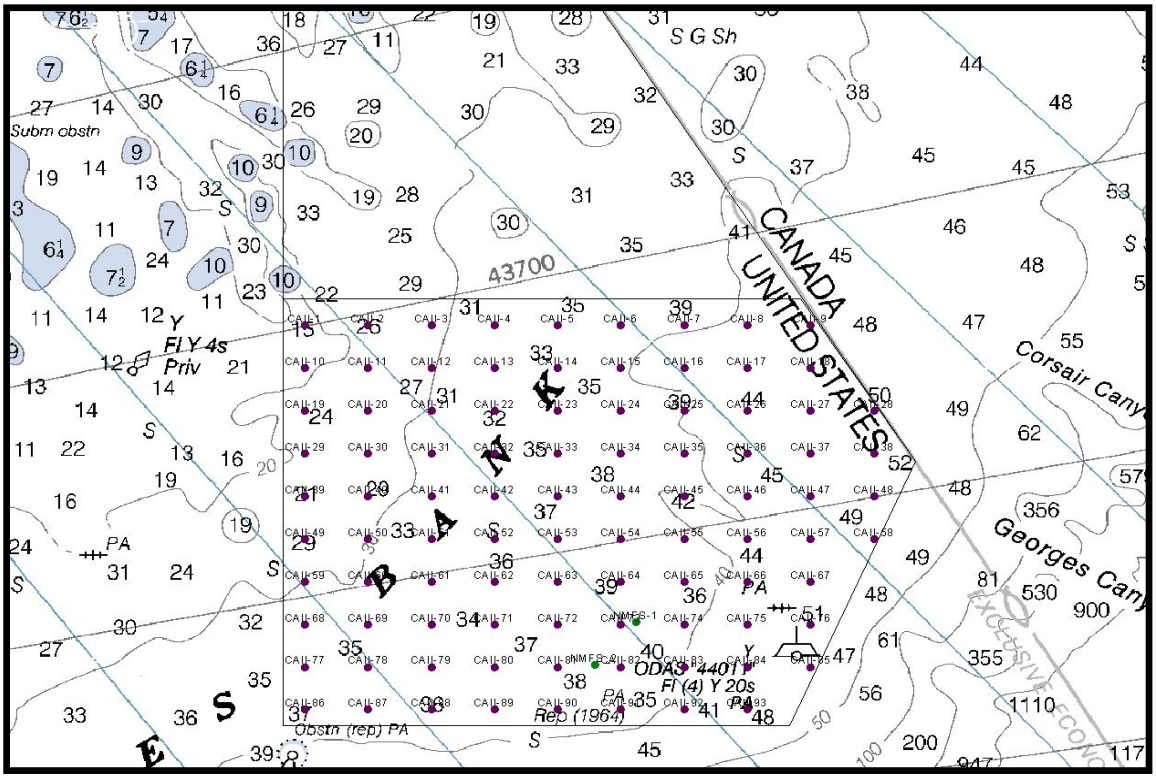


Figure 2 Locations of sampling stations in the exemption area of the Nantucket Lightship and Georges Bank Closed Area I survey by the F/V *Celtic* during the cruise conducted during September 2007.

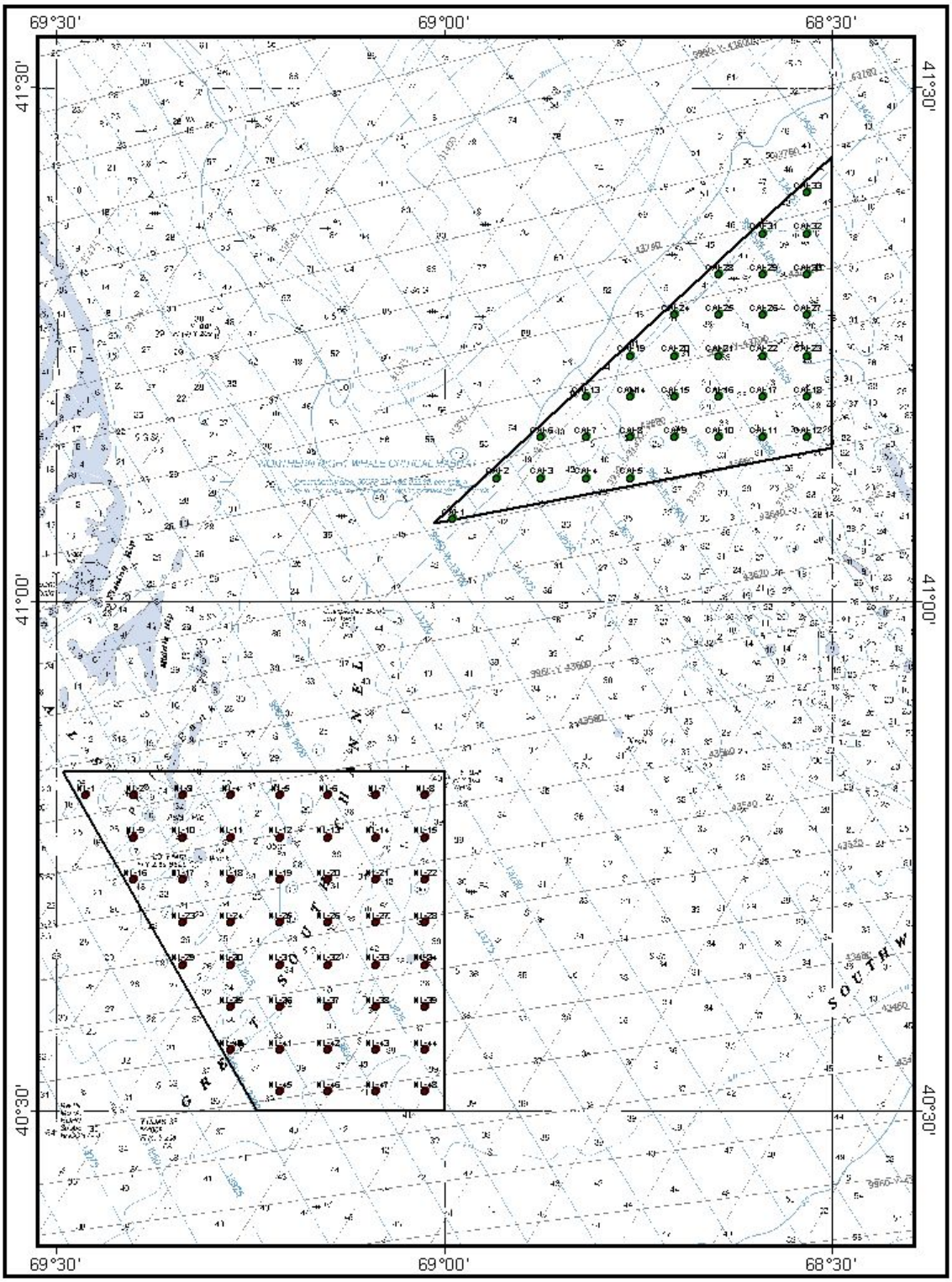


Figure 3 Locations of sampling stations in the Elephant Trunk Closed Area surveyed by the F/V *Pursuit* during the cruise conducted during October 2007.

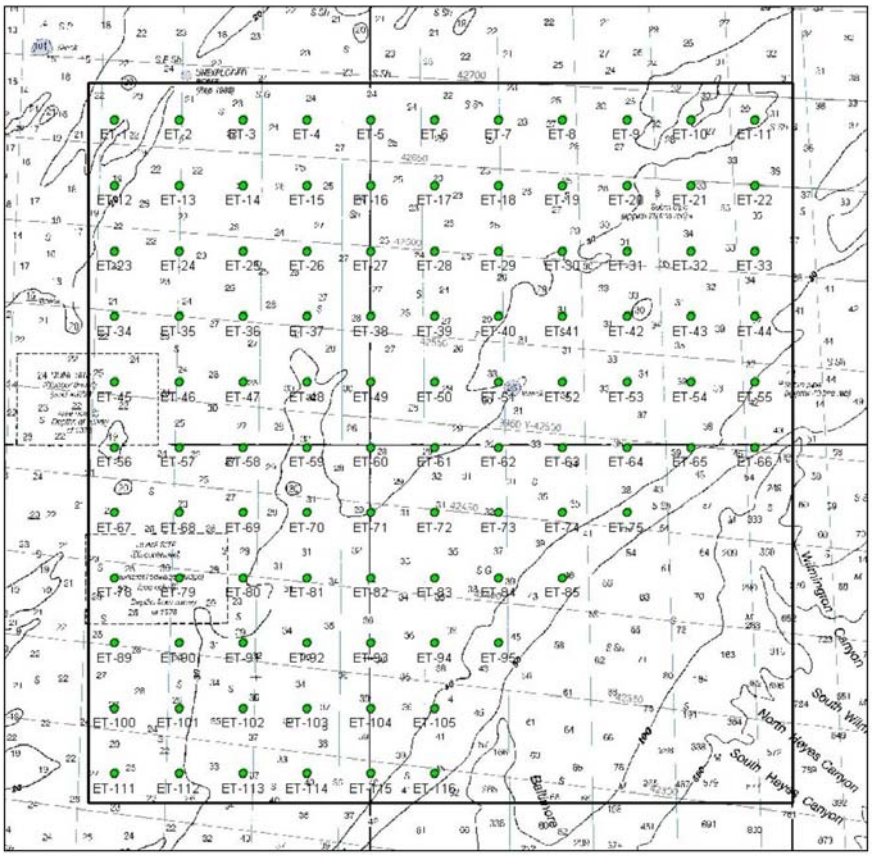


Figure 4 Shell height frequencies for the two dredge configurations used to survey the exemption area of Georges Bank Closed Area II during May 2007. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

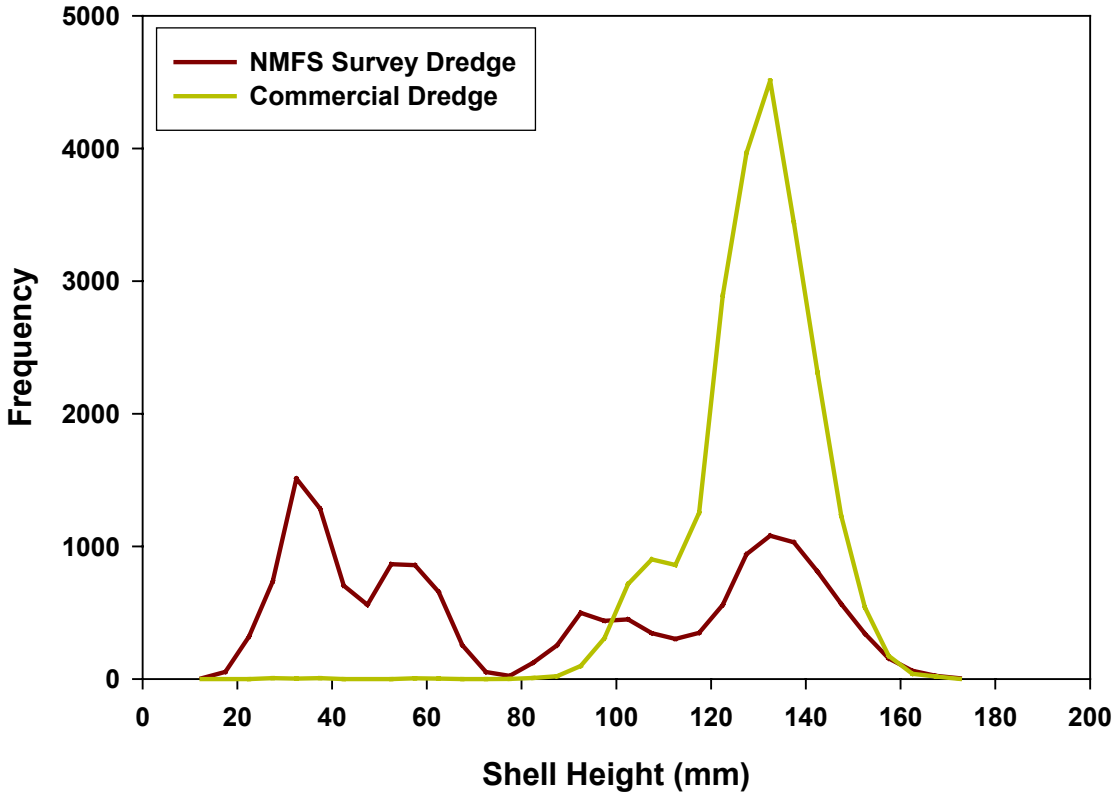


Figure 5 Shell height frequencies for the two dredge configurations used to survey the exemption area of the Nantucket Lightship Closed Area during September 2007. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

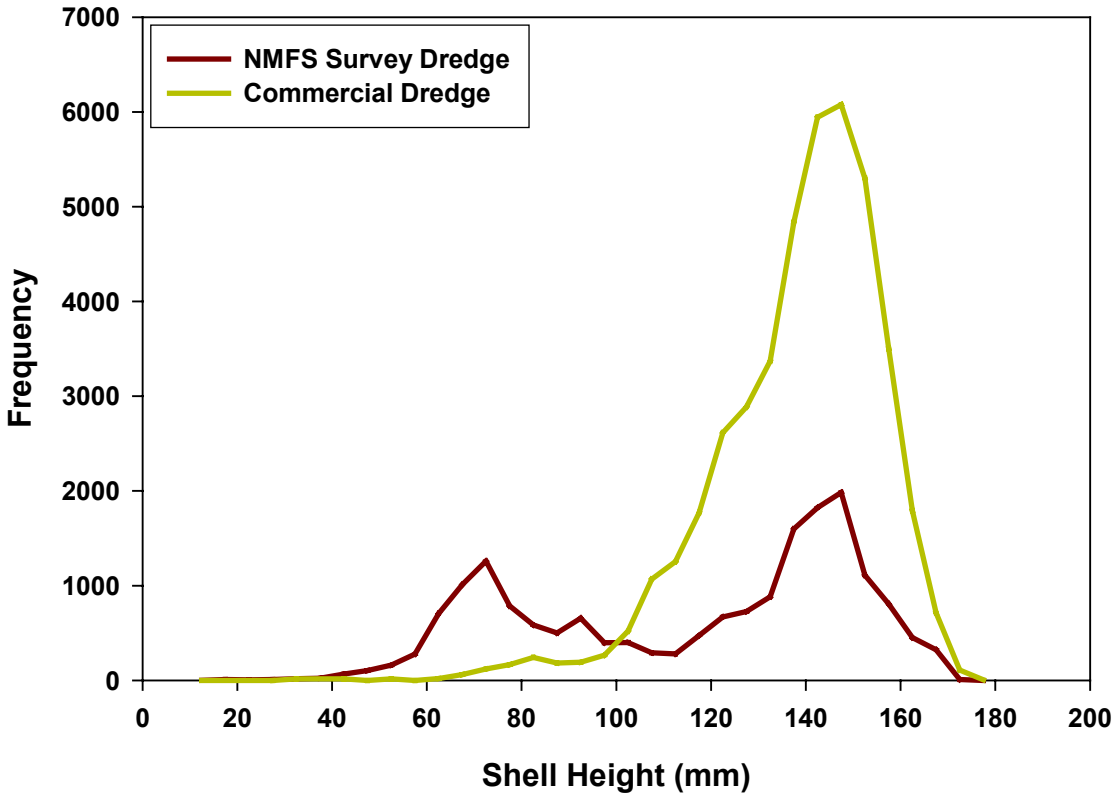


Figure 6 Shell height frequencies for the two dredge configurations used to survey the exemption area of Georges Bank Closed Area I during September 2007. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

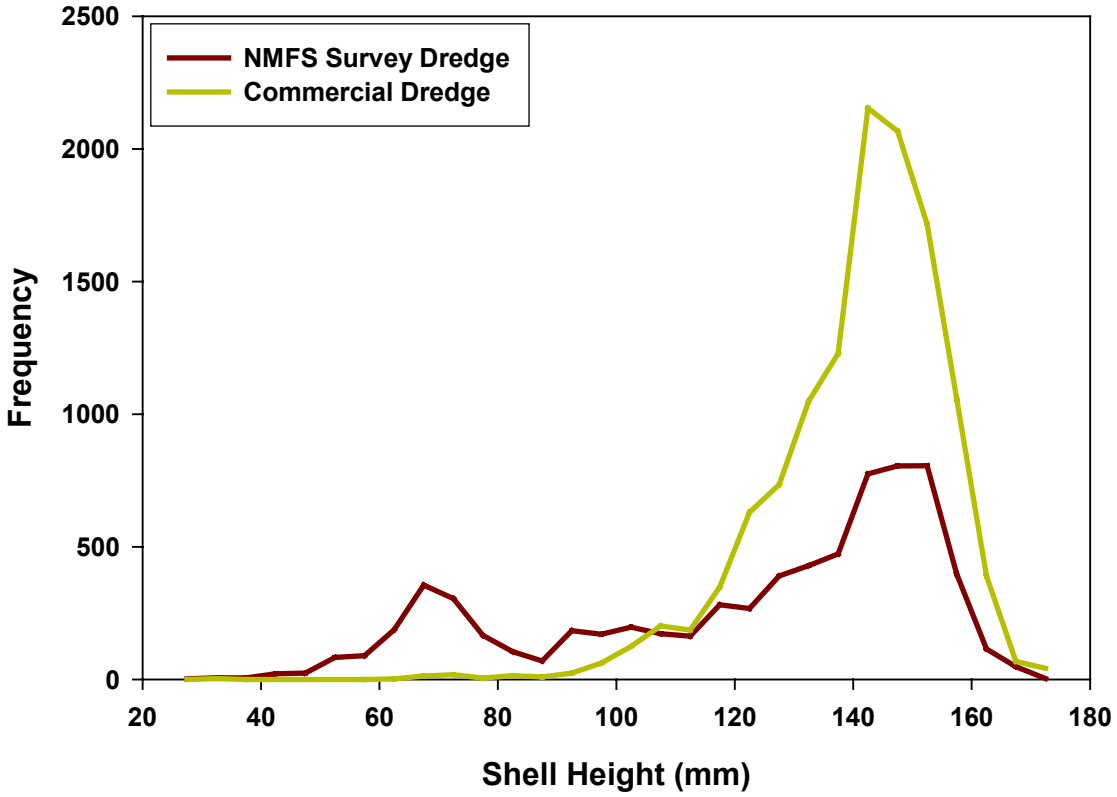


Figure 7 Shell height frequencies for the two dredge configurations used to survey the exemption area of the Elephant Trunk Closed Area during October 2007. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

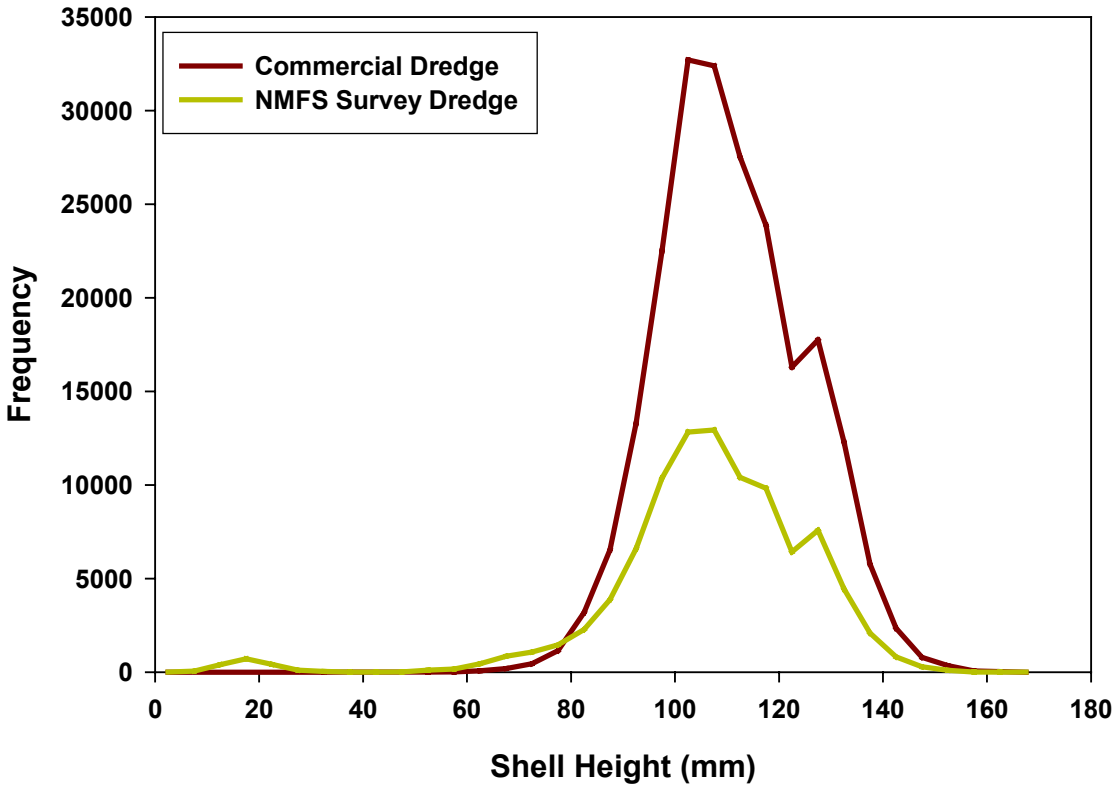


Figure 8 Spatial distribution of sea scallop catches on survey cruise to Georges Bank Closed Area 2 during May 2007 by the commercial dredge. This figure represents the catch of pre-recruit sea scallops (<90mm).

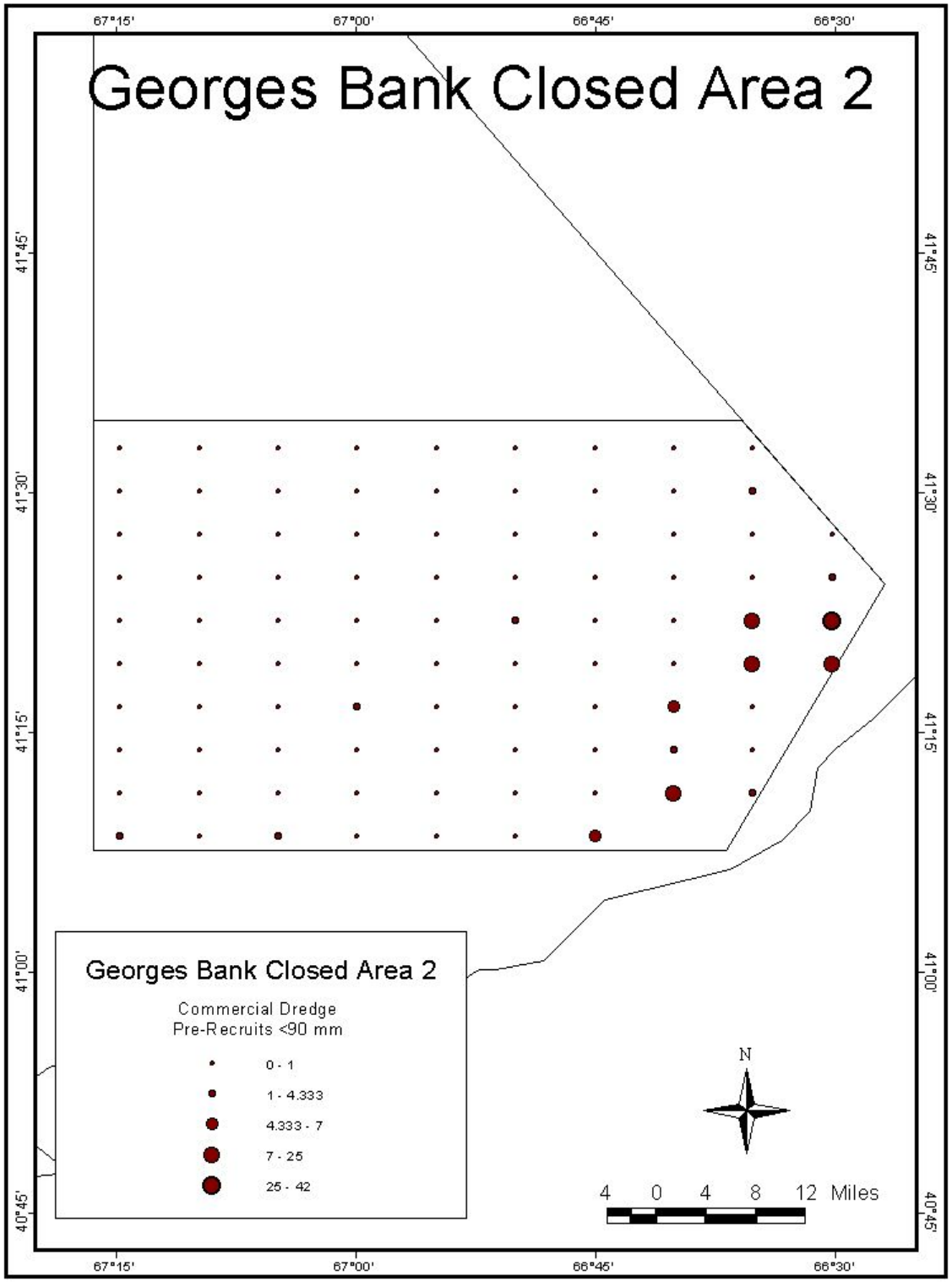


Figure 9 Spatial distribution of sea scallop catches on survey cruise to Georges Bank Closed Area 2 during May 2007 by the commercial dredge. This figure represents the catch of fully recruited sea scallops (>90mm).

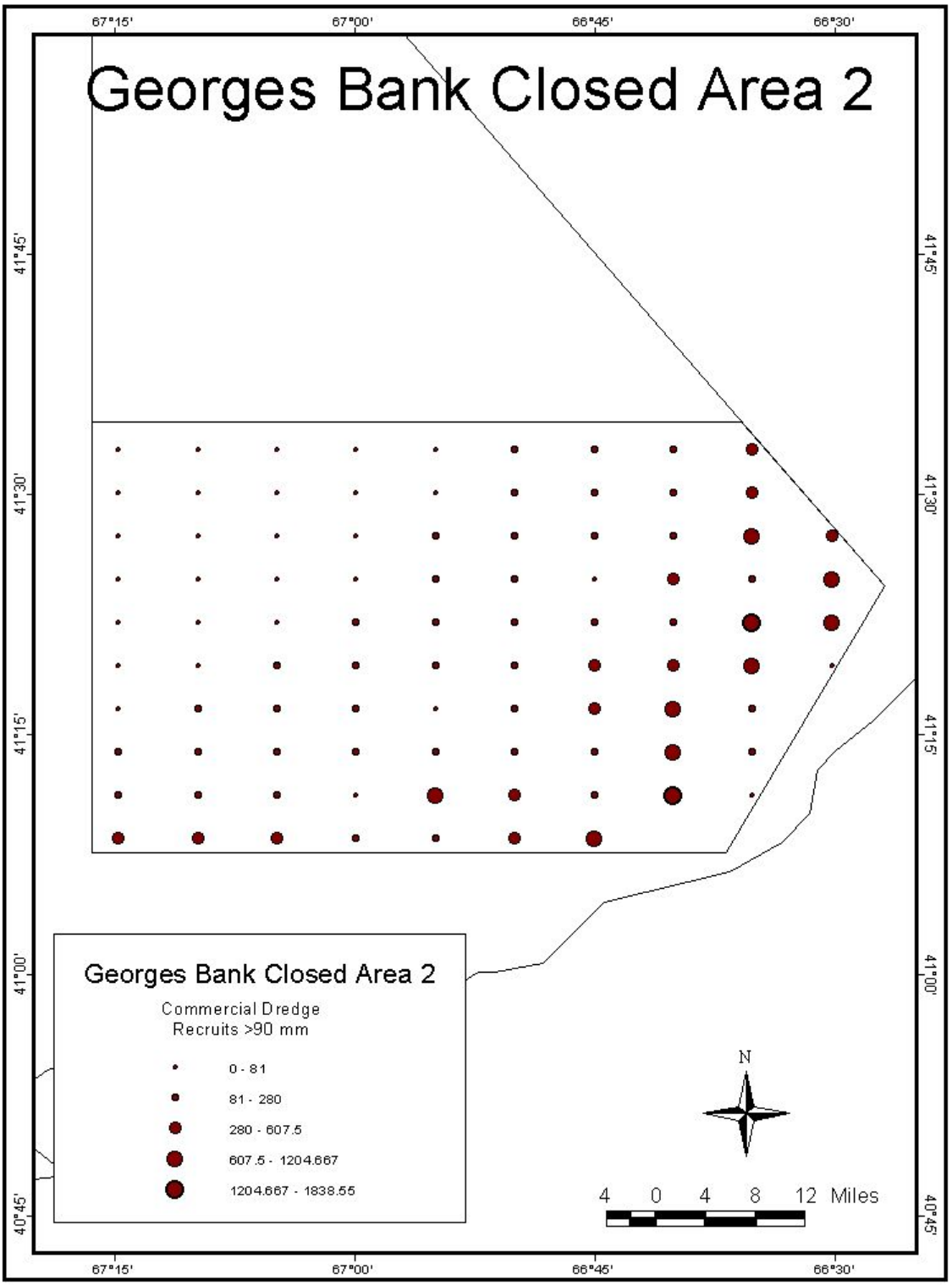


Figure 10 Spatial distribution of sea scallop catches on survey cruise to Georges Bank Closed Area 2 during May 2007 by the NMFS standard survey dredge. This figure represents the catch of pre-recruit sea scallops (<90mm).

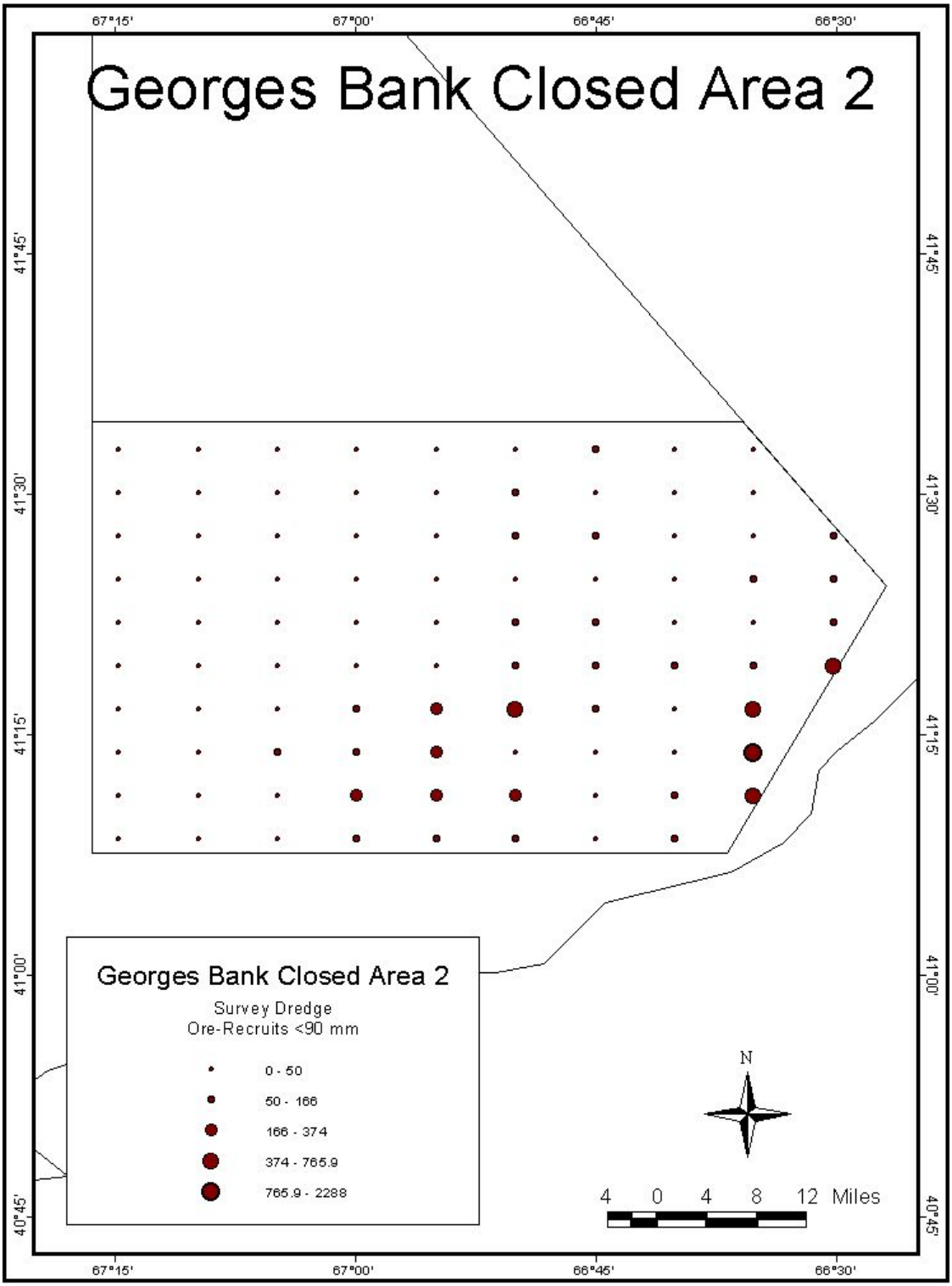


Figure 11 Spatial distribution of sea scallop catches on survey cruise to Georges Bank Closed Area 2 during May 2007 by the NMFS standard survey dredge. This figure represents the catch of fully recruited sea scallops (>90mm).

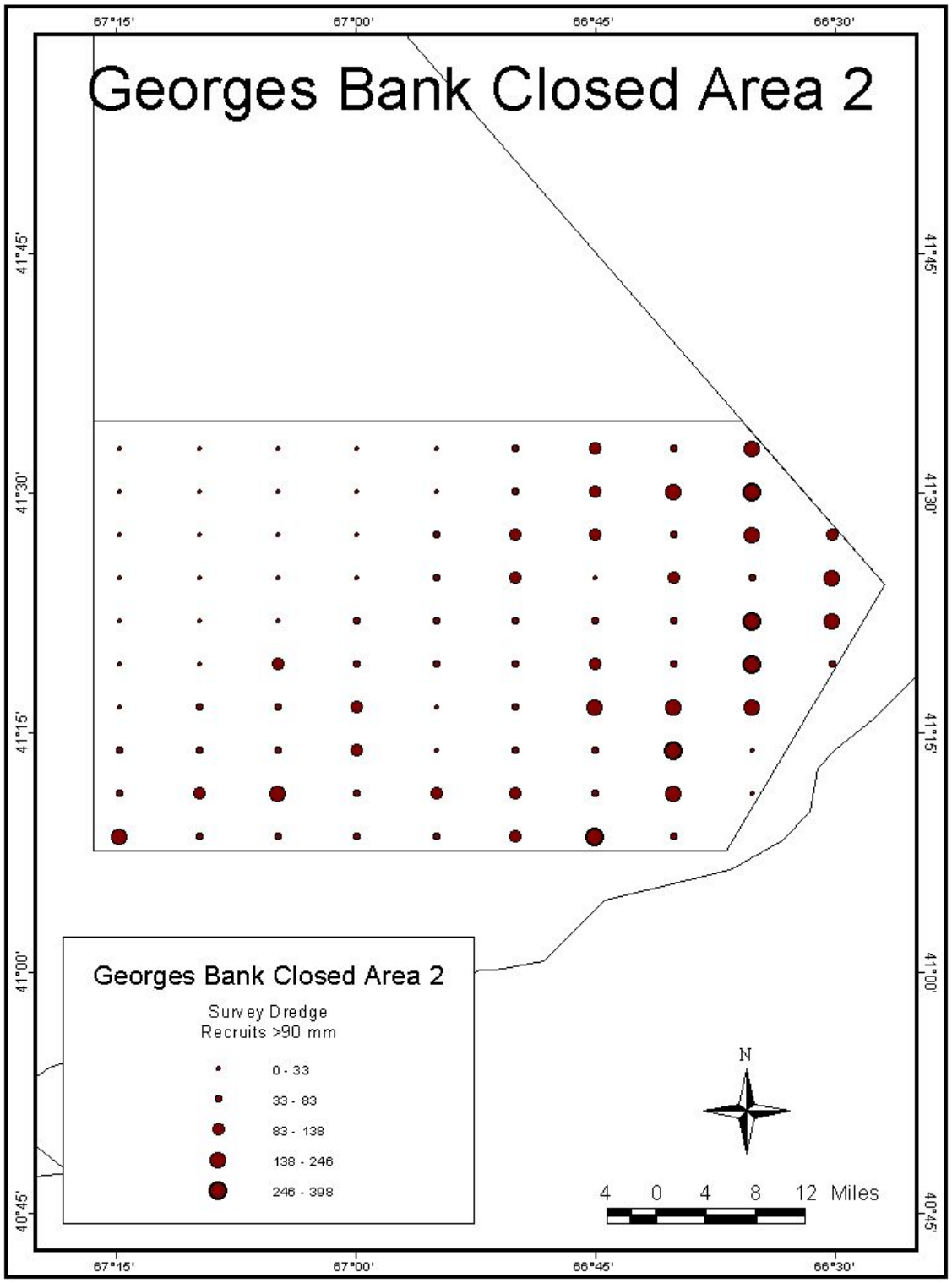


Figure 12 Spatial distribution of sea scallop catches on survey cruise to the Nantucket Lightship and Georges Bank Closed Area 1 during September 2007 by the commercial dredge. This figure represents the catch of pre-recruit sea scallops (<90mm).

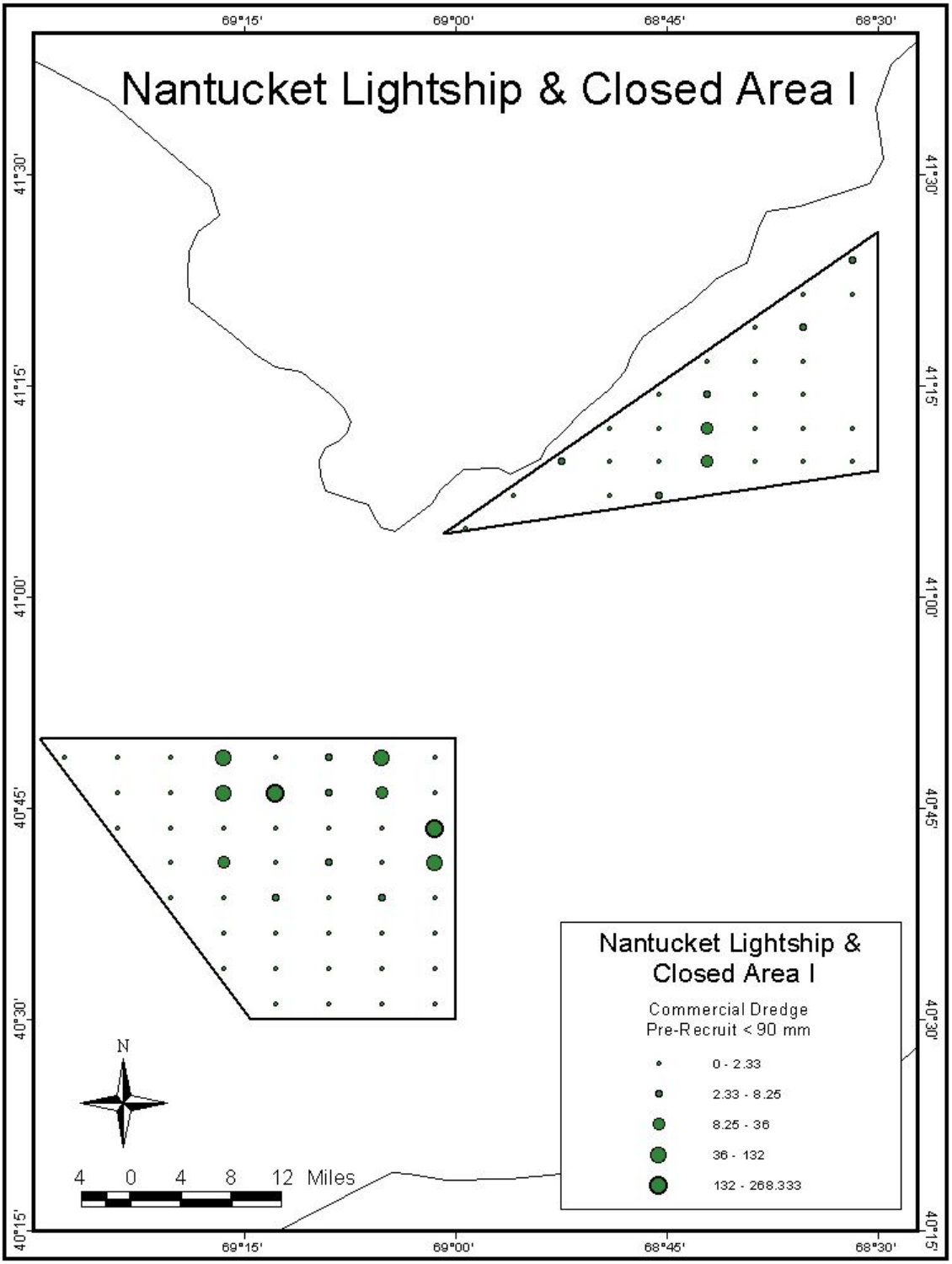


Figure 13 Spatial distribution of sea scallop catches on survey cruise to the Nantucket Lightship and Georges Bank Closed Area 1 during September 2007 by the commercial dredge. This figure represents the catch of fully recruited sea scallops (>90mm).

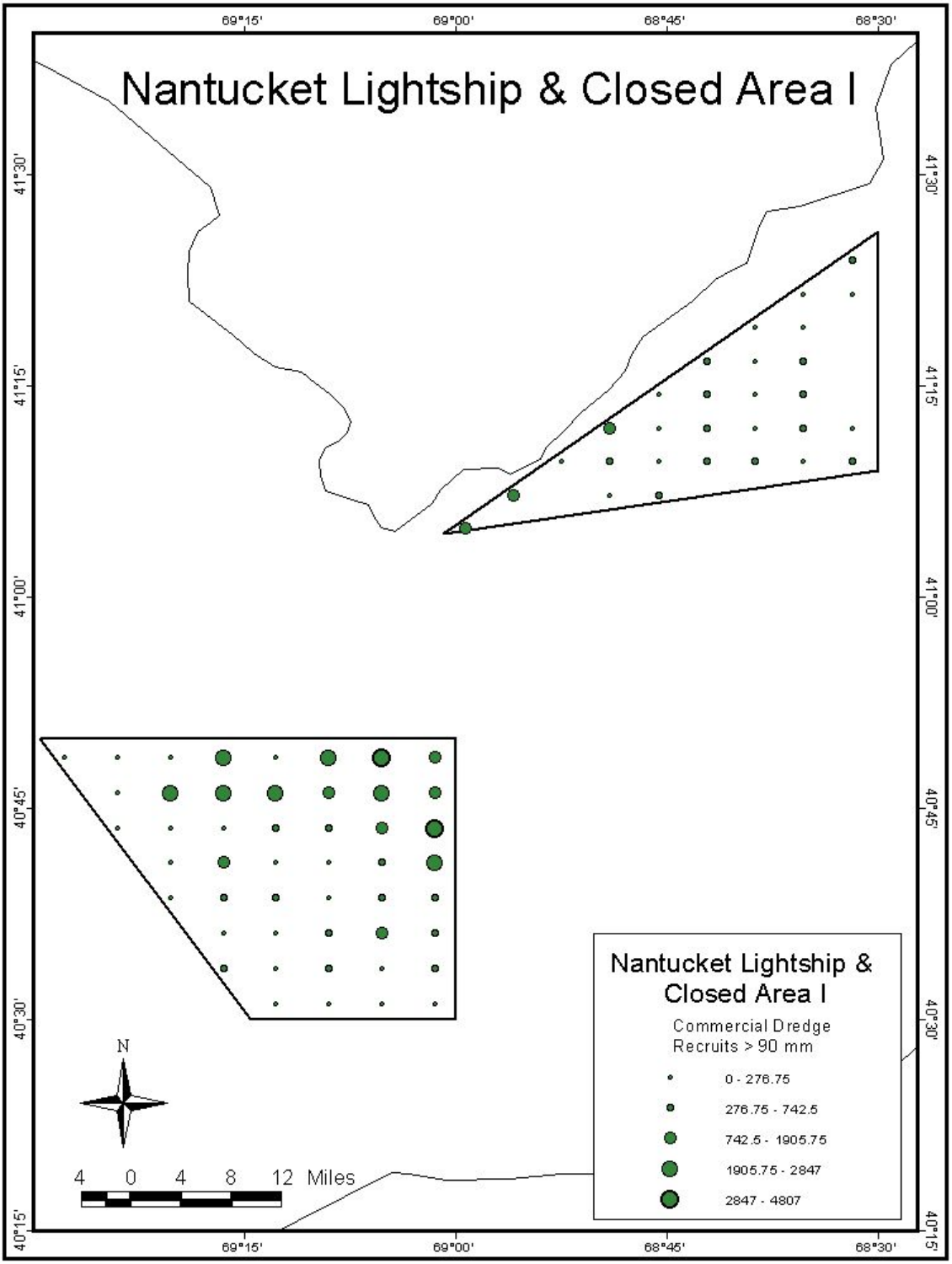


Figure 14 Spatial distribution of sea scallop catches on survey cruise to the Nantucket Lightship and Georges Bank Closed Area 1 during September 2007 by the NMFS standard survey dredge. This figure represents the catch of pre-recruit sea scallops (<90mm).

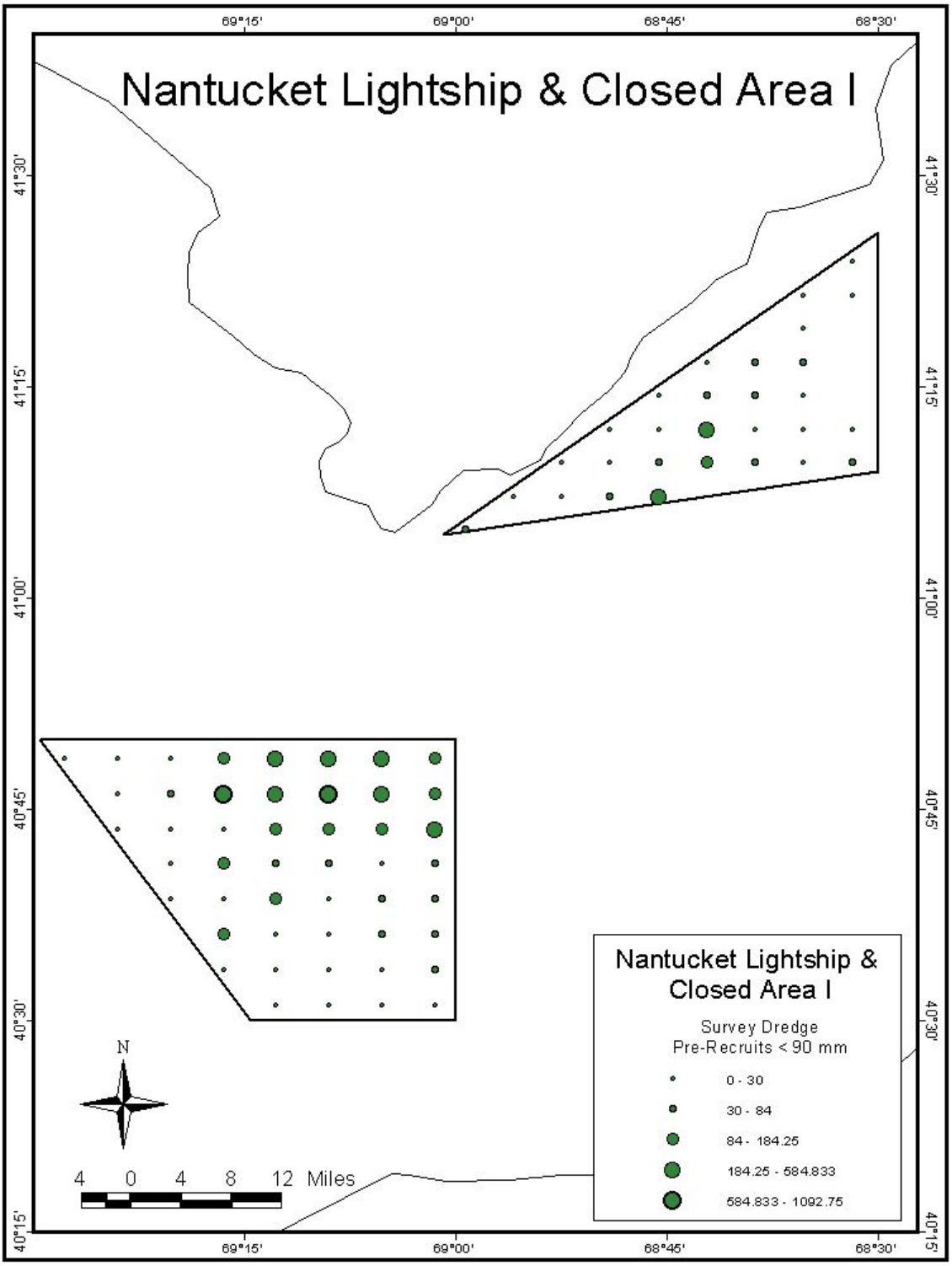


Figure 15 Spatial distribution of sea scallop catches on survey cruise to the Nantucket Lightship and Georges Bank Closed Area 1 during September 2007 by the NMFS standard survey dredge. This figure represents the catch of fully recruited sea scallops (>90mm).

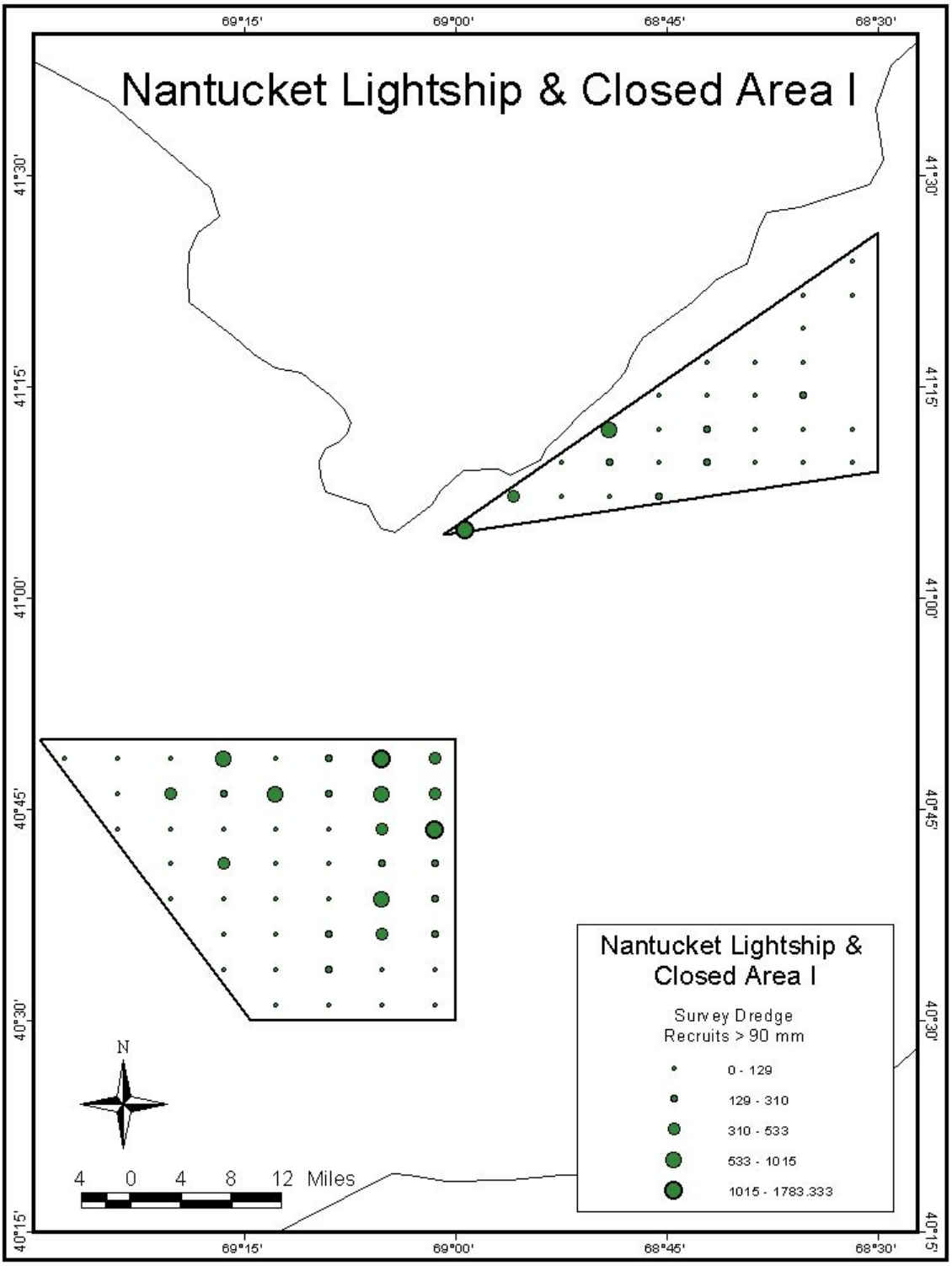


Figure 16 Spatial distribution of sea scallop catches on survey cruise to the Elephant Trunk Closed Area during October 2007 by the commercial dredge. This figure represents the catch of pre-recruit sea scallops (<90mm).

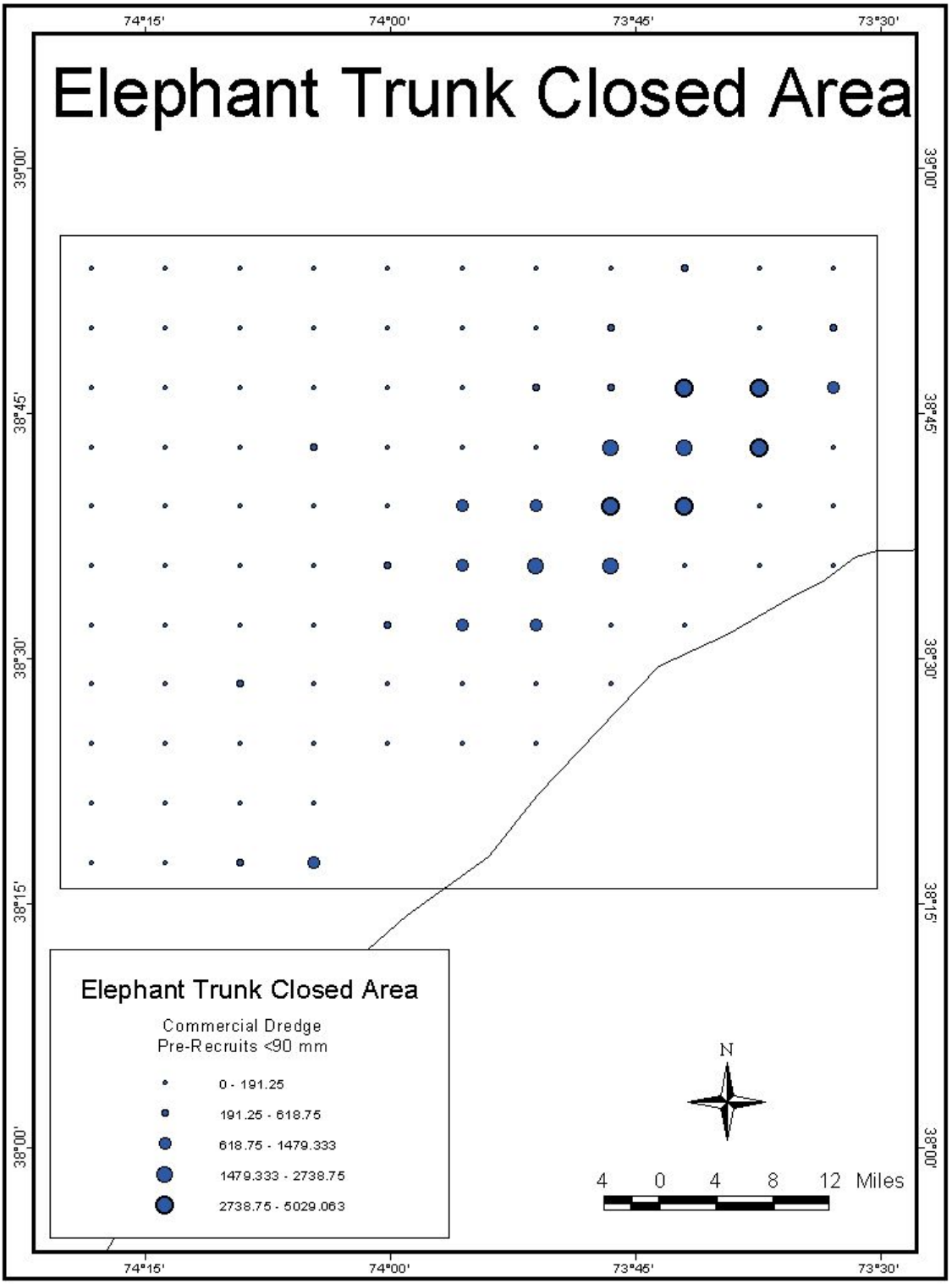


Figure 17 Spatial distribution of sea scallop catches on survey cruise to the Elephant Trunk Closed Area during October 2007 by the commercial dredge. This figure represents the catch of fully recruited sea scallops (>90mm).

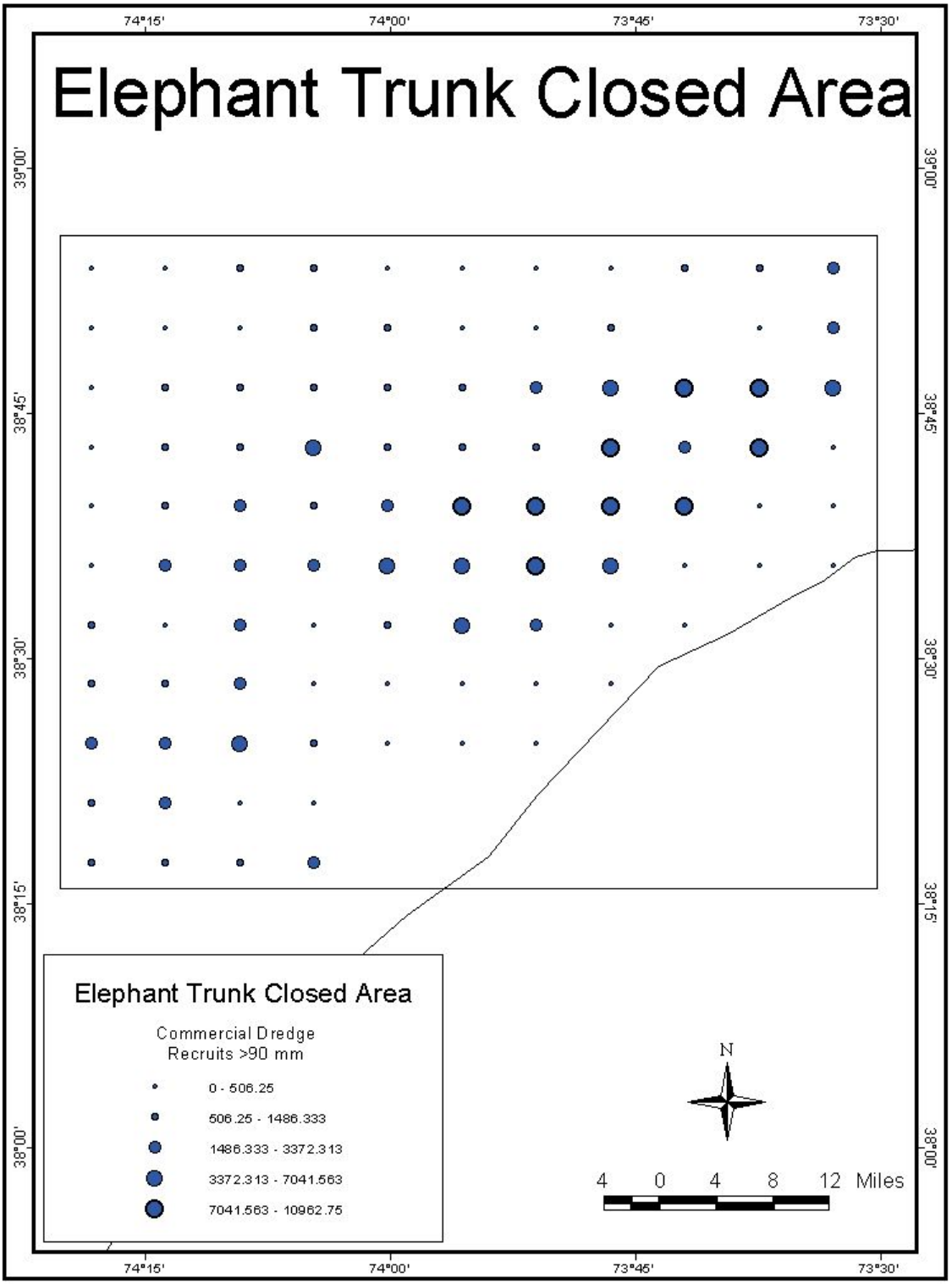


Figure 18 Spatial distribution of sea scallop catches on survey cruise to the Elephant Trunk Closed Area during October 2007 by the NMFS standard survey dredge. This figure represents the catch of pre-recruit sea scallops (<90mm).

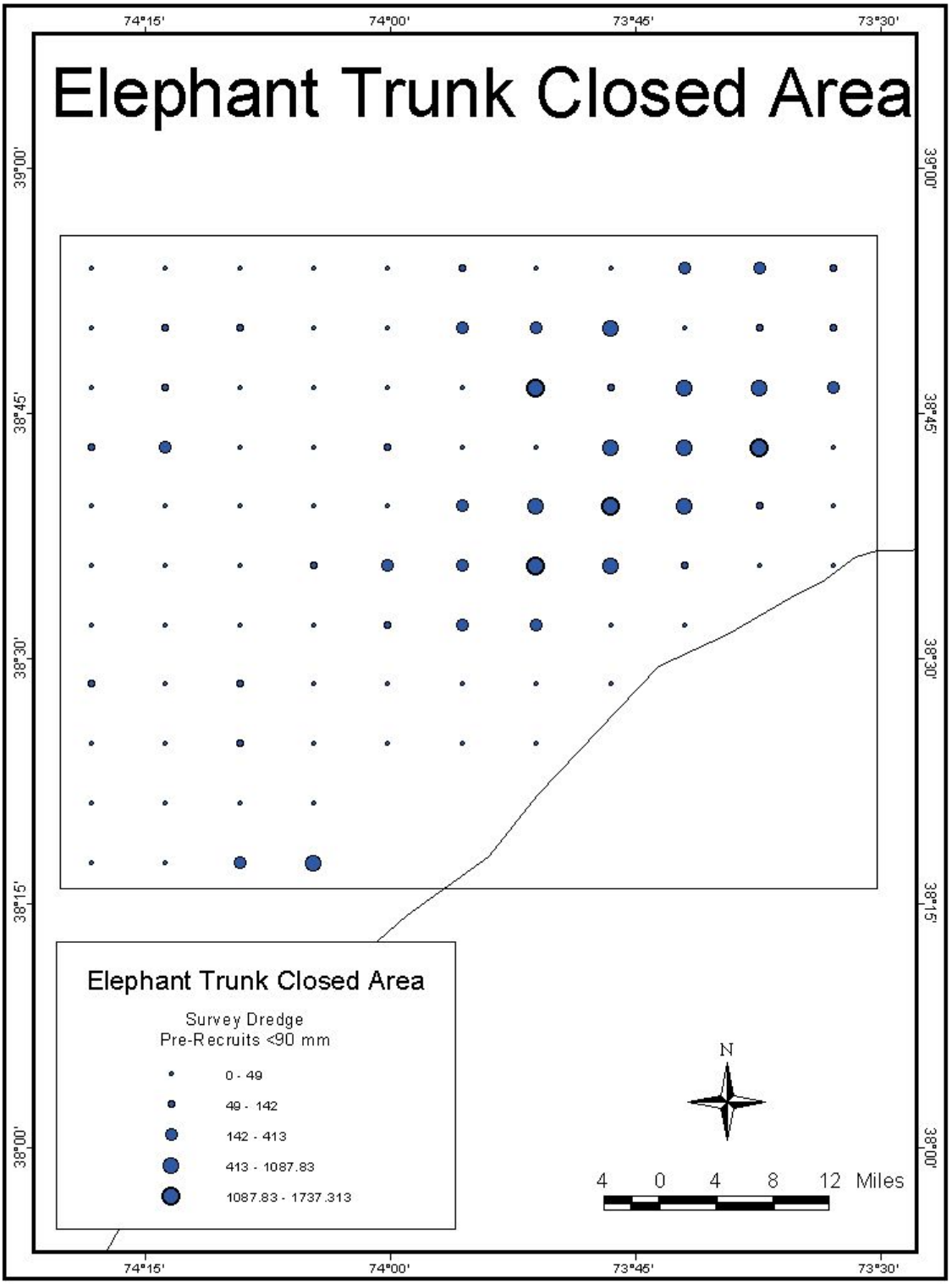
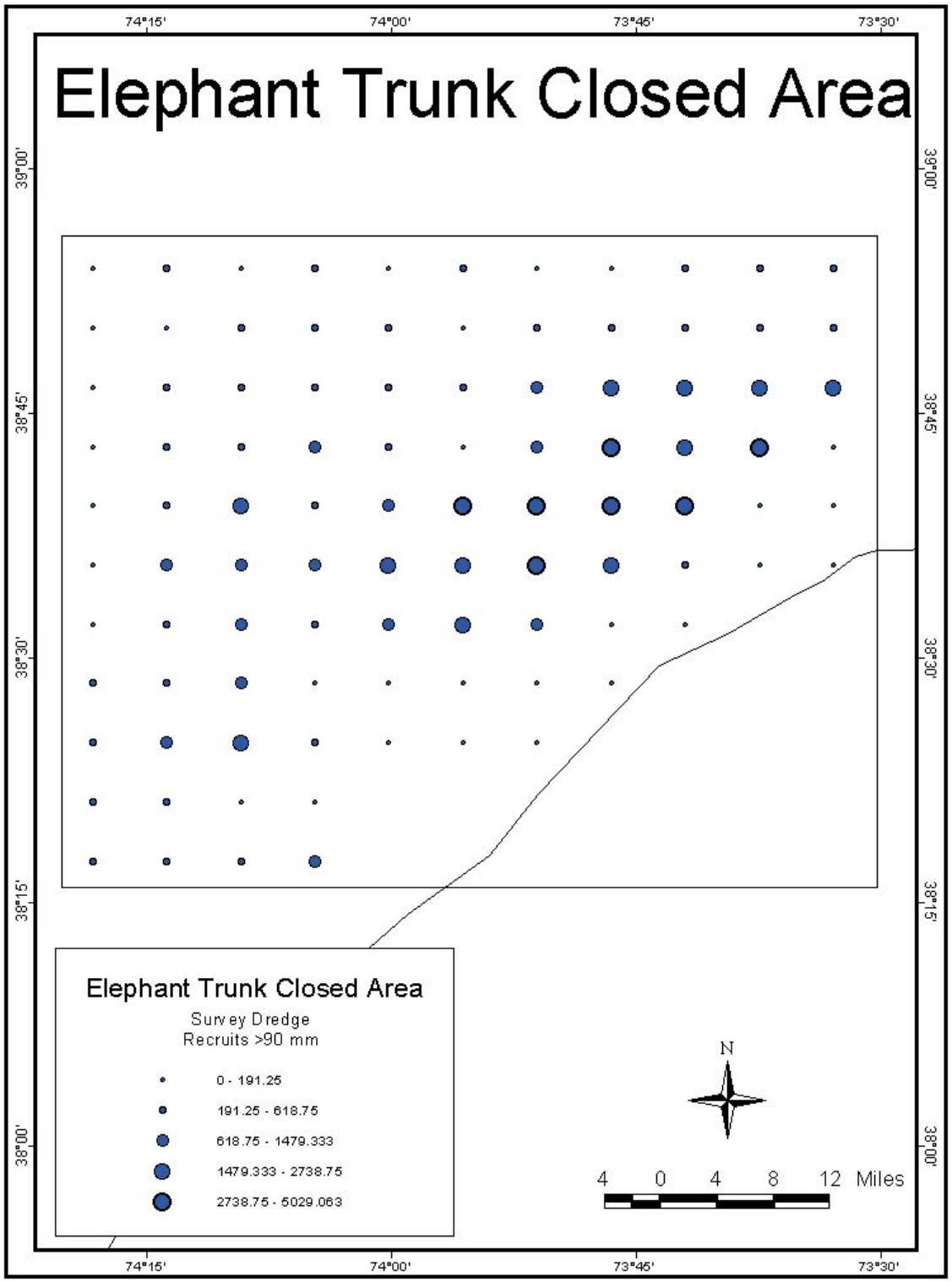


Figure 19 Spatial distribution of sea scallop catches on survey cruise to the Elephant Trunk Closed Area during October 2007 by the NMFS standard survey dredge. This figure represents the catch of fully recruited sea scallops (>90mm).



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Addendum

An Assessment of Sea Scallop Abundance and Distribution in the Southern Portion of Closed Area I

This addendum will serve as a supplement to the report entitled, "An Assessment of Sea Scallop Abundance and Distribution in Selected Closed Areas: Georges Bank Area I and II, Nantucket Lightship and Elephant Trunk". In addition to the closed areas that were surveyed as part of this award, we were able to gather additional information for a discrete area of particular concern. Through donated vessel time from Quinn Fisheries, Inc. in conjunction with two planned survey cruises, we were able to conduct survey operations in the southern portion of the access area of Georges Bank Closed Area I. The coordinates of the area sampled are shown in Figure I. For this additional work the same experimental design, sampling protocol and analysis was followed as in the surveys of the other closed areas during 2007. The tables, graphs and figures that follow summarize our findings in this area.

Table 1 Boundary coordinates of the southern portion of Georges Bank Closed Area I (southern portion) sampled during 2007.

Area Surveyed	Latitude	Longitude
Closed Area I Access Area (southern portion)		
CAI05-1	41° 4.54' N	69° 0.9' W
CAI05-2	41° 09' N	68° 30' W
CAI05-3	40° 58' N	68° 30' W
CAI05-4	40° 55' N	68° 53' W

Table 2 Summary statistics for the survey cruises.

Area	Cruise dates	Number of stations included in biomass estimate (survey dredge)	Number of stations included in biomass estimate (comm. dredge)
Georges Bank Closed Area I- southern portion	May 30, 2007, September 20, 2007	28	-

Table 3 Mean catch of sea scallops observed during the 2007 VIMS-Industry cooperative survey of the southern portion of Georges Bank Closed Area I. Mean catch is depicted as a function of a regional shell height:meat weight relationship from SARC 45.

Gear	Samples	SH:MW	Efficiency	Mean (grams/tow)	Standard Error
GBCAI					
Survey	28	SARC 45	32%	6,892.3	2,454.0

Table 4 Mean total and mean exploitable scallop densities observed during the 2007 cooperative sea scallop survey of Georges Bank Closed Area I.

Gear	Efficiency	Average Total Density (scallops/m^2)	SE	Average Density of Exploitable Scallops (scallops/m^2)	SE
GBCAI					
Survey	32%	0.126	0.039	0.052	0.017

Table 5 Estimated exploitable biomass of sea scallops observed during the 2007 VIMS-Industry cooperative survey of Georges Bank Closed Area I. Biomass is depicted is depicted as a function of a regional shell height:meat weight relationship from SARC 45.

Gear	SH:MW	Efficiency	Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
GBCAI						
Survey	SARC 45	32%	3,633.0	1,434.2	2,198.7	5,067.2

Table 6 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish and invertebrate bycatch encountered during the survey of the exemption area in Georges Bank Closed Area I (pre 2005 southern portion see above for coordinates) during May and September 2007. In total, finfish and invertebrate bycatch was measured and recorded for 29 survey tows.

Common Name	Scientific Name	Survey Dredge
Unclassified Skates	*Raja spp.*	21.586
Barndoor Skate	*Raja laevis*	0.034
Silver Hake	*Merluccius bilinearis*	0.172
Haddock	*Melanogrammus aeglefinus*	0.069
Red Hake	*Urophycis shuss*	2.310
American Plaice	*Hippoglossoides platessoides*	0.034
Summer Flounder	*Paralichtys dentatus*	0.172
Fourspot Flounder	*Paralichtys oblongotus*	0.897
Yellowtail Flounder	*Limanda ferruginea*	2.586
Blackback Flounder	*Psuedopleuronectes americana*	0.655
Witch Flounder	*Glyptocephalus cynoglossus*	0.034
Windowpane Flounder	*Scophthalmus aquasus*	1.931
Sculpin uncl.	*Cottidae*	2.333
Sea Raven	*Hemitripterus americanus*	0.241
Monkfish	*Lophius americanus*	0.138
Eelpout Uncl.	*Zoarcidae*	0.552

Figure 1 Locations of sampling stations in the exemption area of Georges Bank Closed Area I surveyed by the F/V *Celtic* during the cruises conducted during May and September 2007.

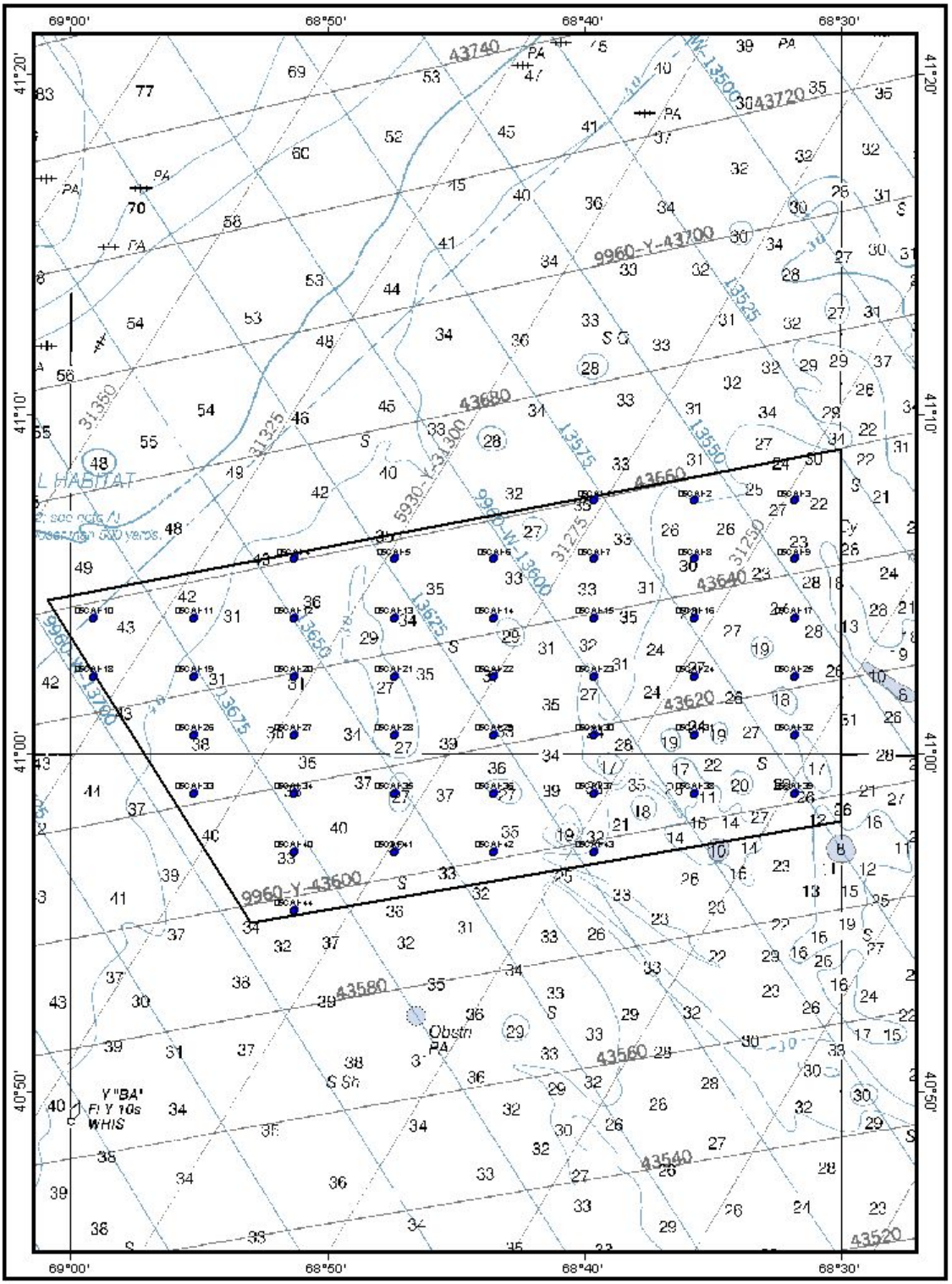

Figure 2 Shell height frequency for the standard NMFS dredge used to survey the previous exemption area (southern portion) of Georges Bank Closed Area I during May and September 2007. The frequency represents the expanded but unadjusted catch for all sampled tows.

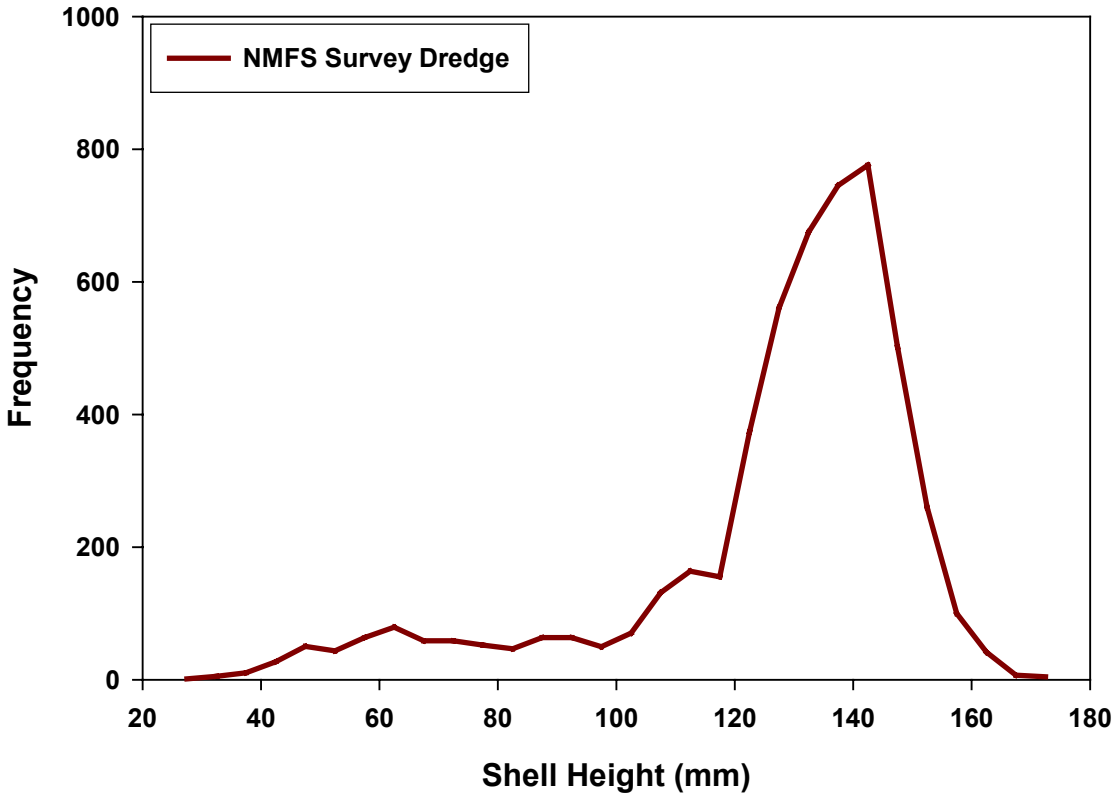

Figure 3 Spatial distribution of sea scallop catches on the survey cruises to Georges Bank Closed Area 1 during May and September 2007 by the NMFS Standard survey dredge. This figure represents the catch of pre-recruit sea scallops (<90mm).

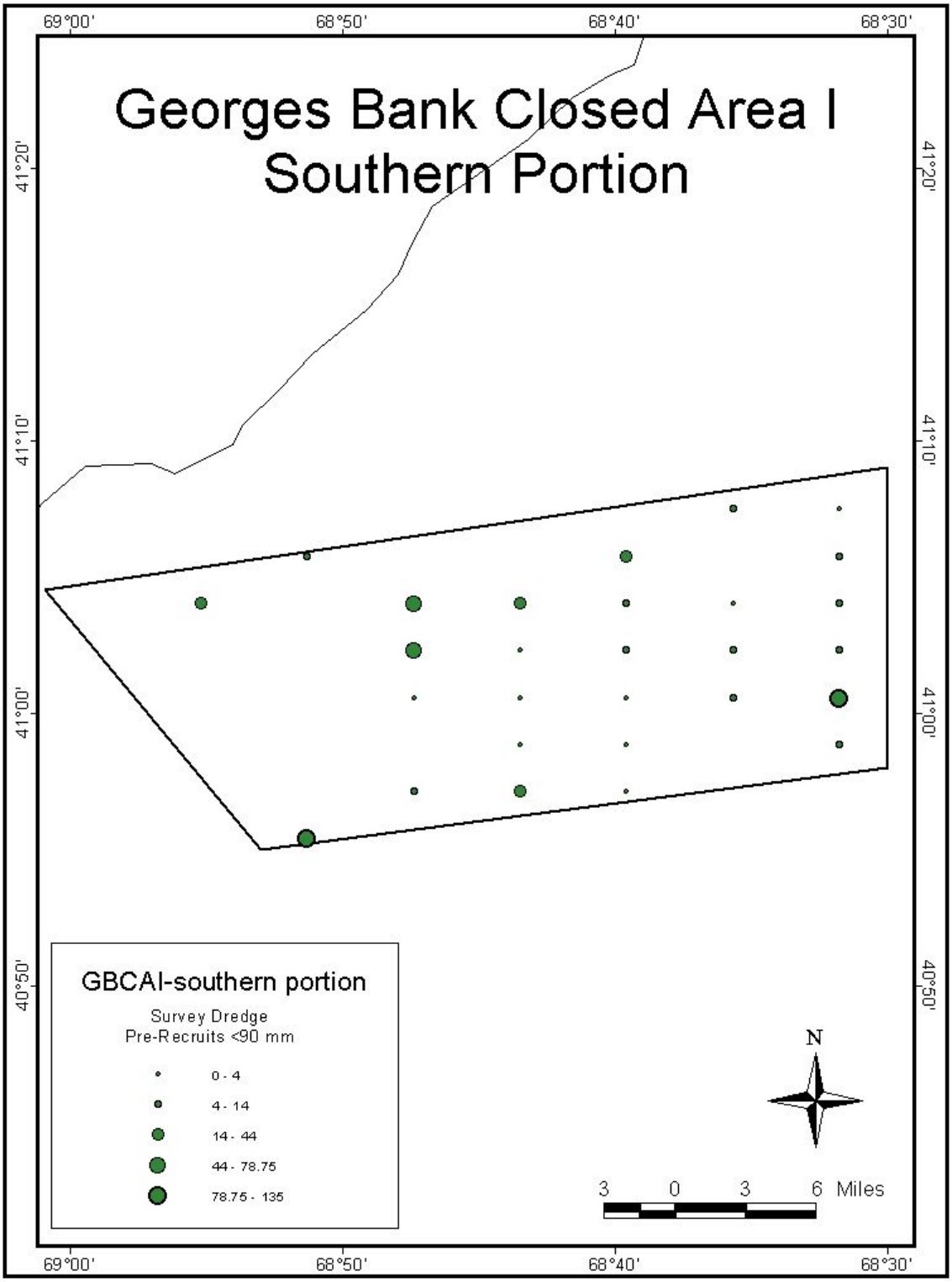

Figure 4 Spatial distribution of sea scallop catches on the survey cruises to Georges Bank Closed Area 1 during May and September 2007 by the NMFS Standard survey dredge. This figure represents the catch of fully recruited sea scallops (>90mm).